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STUDY OF CRISIS UTILIZATION OF LARGE SHELTER SPACE.(U)
AUG 77 M D WRIGHT, S B YORK, R H HILL DCPA01-76-C-0318

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August 1977

DCPA Work Unit 1217E

Contract No. DCPA 01-76-C-0318

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FINAL REPORT 44U-1340

STUDY OF CRISIS UTILIZATION OF LARGE SHELTER SPACE

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RESEARCH TRIANGLE INSTITUTE
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FINAL REPORT 44U-1340 STUDY OF CRISIS UTILIZATION OF LARGE SHELTER SPACE August 1977

RESEARCH TRIANGLE INSTITUTE
OPERATIONS ANALYSIS DIVISION
APPLIED ECOLOGY DEPARTMENT
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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DETACHABLE SUMMARY

FINAL REPORT 44U-1340

August 1977

Study of Crisis Utilization of Large Shelter Space

by

M. D. Wright, S. B. York, III, R. H. Hill, and J. S. McKnight

for

DEFENSE CIVIL PREPAREDNESS AGENCY
Washington, D. C. 20301

under

Contract No. DCPA 01-76-C-0318 new
DCPA Work Unit 1217E

SUMMARY

I. INTRODUCTION AND OBJECTIVES

Under the concept of crisis relocation planning (CRP), during a period of escalating international tensions that have the implication of leading to a nuclear war, people from high-risk areas such as metropolitan communities will be evacuated to outlying rural host areas that have a low risk of receiving direct weapons effects. Though these areas are out of the range of the blast, thermal radiation, and fire effects, shelter still must be provided from radioactive fallout. Much research has been directed into finding methods of improving the fallout protection in existing facilities, but other sheltering aspects have received inadequate attention. This study addresses the provision of lighting, ventilation, potable water, and waste disposal systems for groups of people housed in large facilities, such as government installations, large industrial and commercial buildings, and railroad and highway tunnels. Alternatives are defined for providing these services and examples of the planning required to implement these systems are developed.

II. DEFINITION OF FACILITY CHARACTERISTICS

In this section, building characteristics that are pertinent to the provision of services are identified. Buildings are categorized according to their use into one of eight use classes defined by DCPA. Four different building codes and the results of CRP Host Area Facilities surveys of four counties are used to establish typical values or ranges for existing services in each use class. These data give an indication of the services most likely to require upgrading and of the degree of upgrading that might be required.

III. DESCRIPTION OF OPTIONS FOR PROVIDING SERVICES

A step-wise procedure is used in developing a description of options for providing each of the following services: lighting, ventilation, water supply, excreta disposal, and solid waste disposal. In each case, guidelines are developed upon which to base minimum service requirements, these required levels of service are compared to estimated existing services, and finally, methods of achieving the required upgrading are defined.

Based on the size of the buildings considered in this study, it is assumed that artificial lighting systems are adequate and are already in place. Therefore, guidelines are presented for connecting engine-generators to the existing circuits.

In the ventilation section, it is found that existing ventilation systems provide adequate volumes of air for fallout shelter use in many facilities. The guidelines for connecting engine-generators to existing circuits apply to ventilation as well as to lighting systems. Recommendations are also made for providing forced ventilation in buildings with inadequate or no mechanical ventilation systems.

Of the services addressed in this report, providing water to the people housed in large facilities will probably cause most planning difficulties. A list of questions is presented to aid local planners in determining if the existing water supply is adequate and if it will be available in a shelter situation. Means of achieving and maintaining the necessary purity of water are outlined.

The method of excreta disposal is dependent somewhat on the availability of water, though in most large facilities there is an extreme shortage of permanent toilets. Alternative expedient methods for the sanitary disposal of excreta are presented along with recommendations on when to implement particular disposal facilities.

The solid waste disposal section describes the composition of solid waste and suggests a range of production rates to be used for planning purposes. Several options for the disposal of solid waste are presented.

IV. CLOSE-IN SHELTER FOR KEY WORKERS

Previously completed research is reviewed in an attempt to define the types of close-in shelter that will provide the best blast and fallout protection for key workers. The buildings that are listed in the National Shelter Survey (NSS) meet the fallout protection requirement but few of them offer sufficient blast protection. Only special facilities afford protection from both direct effects and fallout, and this type of shelter is not available near most high-risk areas. It is concluded by RTI that expedient upgrading of existing buildings is the only viable alternative.

V. CONCLUSIONS

In estimating the existing services in buildings and in describing options for providing or augmenting these services, RTI found that existing survey data are inadequate. Additional types of information that would be helpful to local planners for planning purposes are enumerated. In addition, some of the inadequacies of existing guidelines for use as the basis for determining system capacities and material requirements are examined.

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ABSTRACT

This study consisted of an investigation into the options available for utilizing large, special facilities such as tunnels, government installations, and large industrial buildings for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary systems for large groups of people. This task was accomplished by first establishing the existing availability of these services and then identifying ways of augmenting the existing services.

An investigation was also made of the possibilities of suitable close-in shelter for key workers.

All of the analyses were made using existing data already collected, AND

Example problems are included as an appendix.

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I. INTRODUCTION

In the event of an international crisis that has the possibility of ending in a nuclear war, one of the options available to civil defense planners is the dispersion of people from metropolitan areas that have a high risk of direct nuclear attack to outlying host areas that have a low risk of receiving direct weapons effects. A major consideration in the development of such plans is to protect the relocated population from potentially lethal doses of fallout radiation by providing adequate shelter. Since most of the host areas are sparsely populated, only limited numbers of fallout shelter spaces are available as identified in the National Shelter Survey (NSS). Thus, alternative options for shelter provision must be identified and considered in order to provide adequate fallout protection for a relocated population.

One of the options under consideration for providing the needed shelter spaces is the use of large facilities, such as highway and railroad tunnels, government installations, and large industrial buildings. However, many of these facilities will require upgraded sheltering capability. Previously completed research, sponsored by the Defense Civil Preparedness Agency (DCPA), has identified means of improving the fallout protection in such facilities; however, there are other aspects of sheltering large groups of people which have not been addressed. These aspects include the lighting and ventilation of large facilities, the provision for water, and the disposal of excreta and solid waste for large groups of people housed in such facilities. It is to these latter aspects of providing shelter that this study is aimed.

II. OBJECTIVES AND SCOPE

The objective of this report is to evaluate the feasibility of providing crisis-implemented lighting, ventilation, water and sewage handling systems in large facilities used as fallout shelters in Crisis Relocation Planning (CRP) host areas. In addition, close-in shelter for key workers, essential to the continued functioning of the community, is evaluated in terms of survivability at various blast overpressures. Finally, example plans for providing the needed services for several large facilities are presented as a guide to host area planners.

The steps in evaluating the feasibility of providing services to large facilities are to identify information about pertinent building characteristics, to estimate existing services from this information, and to describe methods of complementing existing services. Each of these steps will be addressed in the following sections of this report.

III. DEFINITION OF FACILITY CHARACTERISTICS

This study is concerned with buildings and highway tunnels in host areas with emphasis given to those buildings that are capable of housing large numbers of people (1,000 or more). For this study, buildings are categorized according to their use on the basis of eight use classes developed by DCPA. Table 1 shows the types of buildings that are included in each use class. The use class may, in some instances, give an indication of a building's characteristics. The facility characteristics most relevant to the provision of lighting, ventilation, water and waste disposal systems include existing lights, exterior wall apertures, mechanical ventilation systems, plumbing fixtures, and incinerators.

Under the CRP concept, host area facilities are of two types and the provision of services is significantly different for each type. Facilities which receive and house evacuees in the period of time prior to a nuclear attack are congregate care facilities. Spaces are allocated in these buildings on the basis of 40 square feet per person. Facilities providing (or upgraded to provide) protection from radioactive fallout are shelter facilities. Only 10 square feet per person are allocated in these facilities. Of course, most buildings can serve as both types of shelter. In such a building, sufficient services must be provided to support the people that would be housed during use as a fallout shelter. Tunnels are considered for use only as fallout shelters.

A. Fallout Shelter Facilities

One source of information concerning building characteristics is building codes. Though building codes are general in nature where structural characteristics are concerned, the minimum requirements stipulated for some of the building characteristics in question give a basis for estimating the existing services. RTI consulted the following building codes: the National Building Code 1976, the Standard Building Code, the Building Code of the City of New York, and the Official Building Code of the City of Detroit (Refs. 1, 2, 3, and 4).

Table 2 presents the lighting requirements of the above building codes by use class. Included in this table are the window area requirements for natural light and some artificial light requirements. Similarly, Table 3

Table 1. Types of Buildings Included Under Each Use Class

Building Use	Use Class	Types of Buildings
Residential	10	Apartment/hotel Dormitory/barracks Row houses and duplexes
Educational	20	Kindergarten/elementary school Junior high/high/preparatory school College/university Business/professional/industrial school Correctional schools Library-museum
Religious	30	Church/synagogue Retreat/monastery/convent
Government and Public Services	40	Hospital Clinic Utilities Communication facilities Offices Jails/prisons/correctional institutions Armories/monuments/memorials
Commercial	50	Offices Food stores Stores other than food stores Warehouses Banks/financial institutions
Industrial	60	Factory/plant/manufacturing center Food processing plants
Amusement/Meeting	70	Theatre/auditorium Community center
Transportation	80	Railroad station/terminal Bus station/terminal Airport terminal Airport hangers Marine terminal Automotive repair and storage

Table 2. Lighting Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Light	Artificial Light 1/,2/
National 3/	Residential	10	Habitable rooms shall have 1 or more windows of area not less than 10 percent of the floor area served.	
	Educational Commercial Industrial	20 50 60	Such rooms shall have windows of area not less than 10 percent of the floor area served providing adequate illumination levels as established...4/,	or artificial lighting providing adequate illumination levels as established...4/
	Government and Public Services	40	Habitable rooms shall have 1 or more windows of area not less than 10 percent of the floor area served,	or artificial lighting providing illumination of not less than 30 foot candles at 2-1/2 feet above the floor.
	Religious Amusement/ Meeting Transportation	30 70 80	Such rooms and spaces shall have windows of area not less than 10 percent of the floor area served,	or artificial lighting.
Standard 5/	Habitable room	10-80	Habitable rooms shall have 1 or more windows with glazed openings of clear glass of area not less than 1/10 of the floor area of the room served,	or artificial lighting not less than 50 foot candles.
New York 6/	Occupiable room	10-80	Sources shall have an aggregate transmitting area of at least 10 percent of the floor area of the room or spaces served.	Adequate means for producing artificial light unless rooms or spaces occupied only during daylight hours and are provided with natural light.

(Continued)

Table 2 (cont'd). Lighting Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Light	Artificial Light 1/,2/
Detroit 7/	Occupiable room	10-80	Windows shall have an aggregate area not less than 1/10 the floor area served,	or adequate means for producing artificial light.

1/ If the building code makes no provision for artificial light, then no entry is made in the table.
2/ If the building code calls for either natural or artificial light, then the entry under artificial light begins with "or":.
3/ Ref 1.
4/ Adequate illumination for educational, commercial, or industrial uses is more than adequate for shelter use.
5/ Ref. 2.
6/ Ref. 3.
7/ Ref. 4.

Table 3. Ventilation Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
National 4/	Residential	10	Habitable rooms shall have 1 or more windows of aggregate openable area not less than 1/20th the floor area served.	
	Educational	20	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing a minimum rate of 6 air changes per hour.
	Religious Amusement/ Meeting	30 70	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing from 5 to 15 cfm of outside air per 10 sq. ft.
	Government and Public Services	40	Habitable rooms shall have 1 or more windows of aggregate openable area not less than 1/20th the floor area served,	or in residential restrained care facilities or penal institutions, provisions for not less than 7 air changes per hour and in office buildings 2.5 to 4 cfm of outside air per 10 sq. ft.
	Commercial	50	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing from .5 cfm to 3.3 cfm of outside air per 10 sq. ft. in stores and 2.5 to 4 cfm of outside air per 10 sq. ft. in office buildings.

(Continued)

Table 3 (cont'd). Ventilation Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
	Industrial	60	Such rooms and spaces shall be provided with windows and/or sky-lights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing typically from 15 to 30 cfm of outside air per 10 sq. ft.
	Transportation	80	Such rooms and spaces shall be provided with windows and/or sky-lights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing at least 7.5 cfm of outside air per 10 sq. ft. in garages and 15 to 30 air changes per hour in tunnels.
Standard 5/	Habitable room	10-80	Habitable rooms shall have 1 or more windows that when fully opened shall provide an open area not less than 1/20th the floor area served,	or fresh air in sufficient quantity to maintain healthful conditions as required by State laws or at least equivalent to the required natural ventilation.
New York 6/	Occupiable room	10-80	Such rooms shall have ventilating openings of area at least 5 percent the floor area being served,	or means of providing from 3.3 to 25 cfm of outdoor air per 10 sq. ft.
Detroit 7/	Residential Commercial	10 50	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 2.5 cfm of outdoor air per 10 sq. ft.

(Continued)

Table 3 (cont'd). Ventilation Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
	Educational Religious Amusement/ Meeting	20 30 70	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 3.75 cfm of outdoor air per 10 sq. ft.
	Government and Public Services	40	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 3.75 cfm of outdoor air per 10 sq. ft. to hospitals and 12.5 cfm of outdoor air per 10 sq. ft. to offices.
	Industrial	60	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 5 cfm of outdoor air per 10 sq. ft.
	Transportation	80	Every room or space above grade shall be provided with openings having an area not less than 2 percent of the floor area,	or shall be equipped with the equivalent mechanical ventilation. Below grade space shall be equipped with mechanical ventilation adequate to provide 6 air changes per hour.

1/ If the building code makes no provision for mechanical ventilation, then no entry is made in the table.

2/ If the building code calls for either natural or mechanical ventilation, then the entry under mechanical ventilation begins with "or".

3/ Mechanical ventilation values given for the National Building Code come from Ref. 5.

4/ Ref. 1.

5/ Ref. 2.

6/ Ref. 3.

7/ Ref. 4.

displays the ventilation requirements of the above building codes by use class. Aggregate openable window areas are stipulated for natural ventilation and minimum volumes of mechanical ventilation also are given.

The data in Tables 2 and 3 on lighting and ventilation are considered to be sufficiently detailed and consistent among codes to use as a basis for estimating existing lighting and ventilation services in buildings. However, this is not the case for the data on water supply and sewage disposal. The New York City building code stipulates the minimum number of plumbing fixtures required in buildings of different use classes, and Table 4 presents these data as they apply to buildings used as fallout shelters. Unfortunately, the plumbing data presented in the other building codes are much less specific, necessitating the use of other information sources for estimating existing water supply and sewage disposal services in buildings.

The CRP Host Areas Facility Listing, maintained by DCPA, contains information on use, number of congregate care and shelter spaces, type of water supply, number of commodes, and other pertinent features for each facility surveyed. Therefore, it is an excellent source of information upon which to base estimates of existing water supply and sewage disposal services, as well as to give an indication of the distribution of buildings by use class. Due to time limitations, it was not feasible to analyze these listings for every county that has been surveyed. Therefore, four counties were selected arbitrarily as representative of different geographical regions of the United States. The four counties selected for the analysis are Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; and Yuma County, Arizona.

Table 5 presents a summary of the data on large facilities (i.e. buildings with at least 1,000 shelter spaces) in each county as they were extracted from the listings. In all, a total of 176 facilities are included in the data summary. As shown by the table, educational and government and public services facilities are the most prevalent types of structures; amusement/meeting and transportation facilities are the least prevalent, both from the standpoint of number of total facilities and number of spaces. The table also shows that the number of facilities having sufficient numbers of commodes for the sheltered population is relatively small. A similar shortage is shown in Table 4. A comparison of the deficit of commodes per

Table 4. Minimum Number of Plumbing Fixtures Required 1/

Building Use	Use Class	Occupant Load (sq. ft.per occup.) 2/	Minimum # of Commodes Required 3/	Commodes per 100 People	Deficit of Commodes per 1,000 People 4/	Minimum # of Other Fixtures Required 5/	Watering Points per 100 People	Deficit of Watering Points per 1,000 People 6/
Residential	10	125	167	1.3	7	334	2.7	0
Educational	20	20	20	1.0	10	33	1.7	0
Religious	30	10	5	0.5	15	1	0.1	9
Government and Public Services	40	125	20	0.2	18	37	0.3	7
Commercial	50	25	20	0.8	12	37	1.5	0
Industrial 7/	60	125	20	0.2	18	37	0.3	7
Amusement/ Meeting	70	10	5	0.5	15	5	0.5	5
Transportation 7/	80	125	20	0.2	18	37	0.3	7

1/ Adapted from Ref. 3, Table RS 16-5.
2/ Minimum of ~~Occupant Load~~ Requirements Table 6-2 (Ref. 5) or 125 sq. ft. of net floor area per person stipulated as minimum occupied load in Table RS 16-5.
3/ Assuming 1,000 occupants; 500 men and 500 women, at 10 sq. ft. per occupant.
4/ Based on a minimum requirement of 1 commode per 50 occupants.
5/ Lavatories, bathtubs, showers, or drinking fountains (i.e. watering points).
6/ Based on a minimum requirement of 1 watering point per 100 occupants.
7/ Facilities for employees in a storage building or warehouse may be located in an adjacent building, under the same ownership, where the maximum distance of travel from the working space to the toilet facilities does not exceed 500 ft. horizontally.

Table 5. Four-County 1/ Summary of Large Shelter Facility Characteristics 2/

Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Shelter Spaces	Percent of Total Spaces	Number of Facilities with Basements	Percent of Use Class with Basements	Number of Basement Spaces	Percent of Spaces in Use Class	Water Supply: Public/ Other	Water Supply: Wells	Water Supply: Percent of Use Class w/wells	Water Supply: Percent of Use Class w/water
Residential	10	13	7.4	15,520	2.8	1	7.7	500	3.2	13	0	0.0	100.0
Educational	20	53	30.1	38,353	24.9	6	11.3	2,174	1.6	40	13	24.5	100.0
Religious	30	6	3.4	6,844	1.2	3	50.0	2,838	41.5	6	0	0.0	100.0
Government and Public Services	40	58	33.0	73,114	31.1	18	31.0	16,066	9.3	58	0	0.0	100.0
Commercial	50	29	16.5	95,740	17.2	4	13.8	1,601	1.7	28	1	3.4	100.0
Industrial	60	13	7.4	21,781	21.9	1	7.7	9,999	8.2	11	1	7.7	92.3
Amusement/ Meeting	70	2	1.1	2,100	0.4	1	50.0	1,000	47.6	1	1	50.0	100.0
Transportation	80	2	1.1	2,679	0.5	0	0.0	0	0.0	2	0	0.0	100.0
TOTALS		176	100.0	556,131	100.0	34	19.3	34,178	6.1	159	16	9.1	99.4

(Continued)

Table 5 (cont'd). Four-County 1/ Summary of Large Shelter Facility Characteristics 2/

	Commodes					Generators	
Building Use	Existing Commodes	Facilities w/ Sufficient Number of Commodes 3/	Percent of Use Class w/Sufficient Number of Commodes	Additional Commodes Needed 4/	Deficit of Commodes per 1,000 people	Number w/ Generator	Percent of Use Class w/ Generator
Residential	468	6	46.2	50	3.2	0	0.0
Educational	930	1	1.9	1,869	13.5	0	0.0
Religious	50	0	0.0	89	13.0	0	0.0
Government and Public Services	2,459	24	41.4	1,558	9.0	15	25.9
Commercial	157	0	0.0	1,759	18.4	0	0.0
Industrial	270	0	0.0	2,167	17.8	3	23.1
Amusement/ Meeting	24	1	50.0	18	8.6	0	0.0
Transportation	3	0	0.0	51	19.0	0	0.0
TOTALS	4,361	32	18.2	7,561	13.6	18	10.2

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Large facilities are those facilities listed on the CRP (Crisis Relocation Planning) Host Areas Facility Lighting from 4 arbitrarily selected U.S. counties that have 1,000 or more shelter spaces.
3/ Based on a minimum requirement of 1 commode per 50 shelter spaces.
4/ Commodes needed to bring facilities with fewer than the minimum requirement for commodes up to the minimum number required.

1,000 people between Table 4 and Table 5 shows rather poor agreement in all but the industrial and transportation use classes. Because the data in Table 5 come from actual host area surveys in different parts of the country, it is concluded that these are more representative than the Table 4 data and, consequently, are used in estimating existing services. Finally, the survey data indicate that basements exist in 19.3 percent of the buildings, but contain only 6.1 percent of the total spaces identified.

Railroad and highway tunnels are among the facilities considered as large fallout shelters in this study. Appendix A contains a listing of the major highway tunnels in the United States as compiled by the Federal Highway Administration. Appendix B contains a listing of railroad tunnels compiled in 1940 by the American Association of Railroad Engineers. Railroad tunnels may not be reliable sources of shelter for two reasons: (1) they generally are not easily accessible and, (2) they are too narrow to be used for both shelter and rail transport, which may be vital during a crisis situation. Furthermore, RTI was unable to locate an inventory of railway tunnels more recent than that listed in Appendix B, which was conducted in 1940. On the basis of these observations, RTI feels that railroad tunnels should not be included in the shelter inventory for a host area if there is sufficient space available in other shelter types. Railroad tunnels, therefore, will not be discussed further.

It should be noted that the list of major highway tunnels, given in Appendix A, does not include all highway tunnels, the exception being those that are on National Park Service lands, such as the Blue Ridge Parkway-Skyline Drive belt along the Appalachian Mountains. This particular road system contains about 25 tunnels, and hence, a number of potential fallout shelters. Thus, in some localties, there may be additional shelter space in tunnels which are not included in the tunnels listed in Appendix A. Tables 6 and 7 summarize the characteristics of the major vehicular tunnels, and gives their distribution by length.

The review of building codes by RTI did not yield any information relating to lighting requirements, water supply, or waste disposal in tunnels. Ventilation guidance in the building codes comes from the <u>1974 ASHRAE Application Handbook</u> (Ref. 5) which is referenced by the <u>National Building Code 1976</u> (Ref. 1). The handbook states that, "Underground tunnels under rivers, etc., or long taxi tunnels for discharge of passengers

Table 6. Lengths of Major Vehicular Tunnels in the United States*

Length (in feet) portal to portal		Number of Bores
0 - 1,000		24
1,001 - 2,000		48
2,001 - 3,000		15
3,001 - 4,000		7
4,001 - 5,000		11
5,001 - 6,000		12
6,001 - 7,000		5
7,001 - 8,000		4
8,001 - 9,000		4
9,001 - 10,000		2
	Total	132

* As of September 1975

Adapted from information supplied by the Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., February 1977.

Table 7. Summary of Major U.S. Vehicular Tunnel Characteristics

Tunnel Feature	Characteristic
Length of all tunnels	70.72 miles
Length available for shelter use	65.53 miles
Area for shelter use	10,595,432 sq. ft.
Number of shelter spaces	1,059,520 shelter spaces

to the lower level of buildings should be designed for 15 to 30 air changes per hour. The lower limit applies to taxi tunnels having constant truck and auto traffic." Either of these rates is adequate to support people sheltered at the rate of 10 square feet per person and it may therefore be assumed that the existing ventilation systems in these types of tunnels are adequate--if a source of electric power can be provided.

B. Congregate Care Facilities

For the purpose of this study, the only difference between fallout shelter and congregate care facilities is the greater population density (by a factor of 4) housed in fallout shelter facilities. Therefore, the information contained in Table 2 (concerning the lighting requirements of the building codes) and in Table 3 (concerning the ventilation requirements of the building codes) is directly applicable to congregate care buildings, with one modification. The minimum requirement for mechanical ventilation stipulated in Table 3 in terms of cubic feet per minute (cfm) per 10 square feet should be multiplied by 4 to yield the rate in terms of cfm per 40 square feet (the floor area allocated per congregate care space). Data on congregate care facilities, based on information from the survey of four counties, are contained in Table 8. The data in Table 5 (pertaining to the number of facilities, water supply, and generators) are changed slightly in Table 8 because 10 large congregate care facilities which were not indicated as usable for fallout shelters were identified in the four counties studied. The data on spaces and commodes change considerably between Table 5 and Table 8 as they obviously would considering the differing population density between congregate care facilities and shelter facilities. It should be emphasized that the information in Table 8 is related only to the requirements for resources when the facilities are to be used for congregate care only.

Table 8. Four-County 1/ Summary of Large Congregate Care Facility Characteristics 2/

Building Use	Use Class	Number of Facilities	Congregate Care Spaces	Percent of Total Spaces	Water Supply			
					Public/ Other	Wells	Percent of Use Class w/wells	Percent of Use Class w/water
Residential	10	13	8,018	3.3	13	0	0.0	100.0
Educational	20	53	43,058	17.9	40	13	24.5	100.0
Religious	30	6	2,635	1.1	6	0	0.0	100.0
Government and Public Services	40	58	92,066	38.2	58	0	0.0	100.0
Commercial	50	34	43,401	18.0	33	1	2.9	100.0
Industrial	60	16	48,409	20.1	14	1	6.3	93.8
Amusement/ Meeting	70	2	837	0.3	1	1	50.0	100.0
Transportation	80	4	2,675	1.1	4	0	0.0	100.0
TOTALS		186	241,099	100.0	169	16	8.6	99.5

(Continued)

Table 8 (cont'd). Four-County 1/ Summary of Large Congregate Care Facility Characteristics 2/

Building Use	Commodes: Existing Commodes	Commodes: Facilities with Sufficient Number of Commodes 3/	Commodes: Percent of Use Class w/Sufficient Number of Commodes	Commodes: Additional Commodes Needed 4/	Commodes: Deficit of Commodes per 1,000 people	Generators: Number with Generator	Generators: Percent of Use Class with Generator
Residential	468	13	100.0	0	0.0	0	0.0
Educational	930	33	62.3	192	4.5	0	0.0
Religious	50	3	50.0	11	4.2	0	0.0
Government and Public Services	2,459	34	58.6	193	2.1	15	25.9
Commercial	345	5	14.7	531	12.2	0	0.0
Industrial	350	5	33.3	624	12.9	3	18.8
Amusement/ Meeting	24	1	50.0	2	2.4	0	0.0
Transportation	11	0	0.0	43	16.1	0	0.0
TOTALS	4,637	94	50.5	1,596	6.6	18	9.7

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Large facilities are those facilities listed on the CRP (Crisis Relocation Planning) Host Areas Facility Listing from 4 arbitrarily selected U.S. counties that have 1,000 or more shelter spaces.
3/ Based on a minimum requirement of 1 commode per congregate care space.
4/ Commodes needed to bring facilities with fewer than the minimum requirement for commodes up to the minimum number required.

IV. DESCRIPTION OF OPTIONS FOR PROVIDING SERVICES

The development of descriptions of options for augmenting the existing services in host area shelters was accomplished in three steps. First, guidelines were developed upon which to base estimates of the minimum required services during a shelter stay. Second, the estimated existing services in the types of facilities being considered were evaluated and compared to the required levels. (This indicates the adequacy of existing services and allows specification of the amount of upgrading required.) Finally, methods of achieving the required upgrading were defined.

In the preceding section, facility characteristics were defined for congregate care as well as for fallout shelter facilities. The characteristics of congregate care facilities may be useful as a planning tool, however, for the following reasons, only fallout shelter facilities are considered hereafter: (1) on the basis of the four-county host area survey results presented in Tables 5 and 8, the vast majority of large congregate care facilities also serve as fallout shelters during a crisis period and, therefore, require services to support the greater population that is housed in a fallout shelter, (2) during the time that a facility is used for congregate care, the existing utility and waste disposal services should continue to operate, and (3) while a facility is being used for congregate care there should be no danger from fallout, so sufficient numbers of apertures can be left open to provide light and ventilation, and shelter occupants can find sources of water and means of waste disposal outside the facility.

The following sections describe the options for providing lighting, ventilation, potable water supply, excreta disposal, and solid waste disposal systems in large fallout shelter facilities.

A. Lighting

It is essential to provide at least low levels of lighting throughout a facility being used as a fallout shelter. Some light is needed to allow necessary movement and tasks to be carried on inside the shelter. In fact, it is likely that people will not use unlighted areas. Additionally, in tunnels, which are a more unnatural environment than large buildings, people may become disoriented and frightened if inadequate lighting is provided.

1. Required Lighting

Very minimal levels of light are all that are required in a fallout shelter facility. Levels of light that prevent the shelter occupants from becoming lost and allow them to identify their immediate surroundings are sufficient. Tasks (such as food preparation) for which more light is essential should be performed near a light source.

2. Existing Lighting Systems

Although the building codes referenced in Section III do not require artificial lighting in buildings of any use class, it is assumed that all buildings within the scope of this report will contain some amount of artificial lighting. This assumption is made because only large buildings are being considered and, for these buildings to be used optimally in their designed purpose, adequate artificial lighting systems for fallout shelter use will have been installed. However, in the case of tunnels, it is assumed that there is no existing artificial lighting system. Though some tunnels are lighted, it is likely that most of those located in host areas contain no artificial lighting systems.

The above assumptions lead to the following conclusions concerning the provision of light: (1) the existing lighting circuits in buildings should be connected to available emergency power sources, and (2) complete lighting systems should be installed in tunnels.

The four-county summary of large shelter facility characteristics presented in Table 5 shows that about 25 percent of the buildings in the government and public services and industrial use classes were found to be equipped with emergency generators. This figure represents only 10 percent of all the buildings surveyed. Therefore, in most cases, buildings used as fallout shelters are not equipped with emergency generators, so sources of generators must be identified if existing lighting systems are to be utilized for shelter lighting. This is particularly true if the building is not in the government and public services or industrial use classes.

3. Provision of Lighting

Appendix C identifies some factors to be taken into consideration in utilizing a standby engine-generator in an existing building and presents guidelines for connecting engine-generators to the lighting systems in buildings. If emergency generators are not available in the proper size or voltage, it is necessary to resort to other expedient means of providing lighting, such as candles, kerosene lamps, cooking fat lamps, etc. (Ref. 6).

A highway tunnel is similar in character to a mine in which the usable floor area is located in the haulage drifts. In previous work (Ref. 7), RTI developed detailed instructions for planning a lighting system in such a mine. These instructions are equally applicable to tunnels and should be consulted for guidance in developing tunnel lighting systems.

B. Ventilation

Ventilation of fallout shelter buildings is needed both to maintain the air quality within satisfactory limits, and to maintain the effective temperature at an acceptable level. Temperature control is not generally needed in tunnels because of the larger surface area per person (relative to buildings) that is available to absorb heat. This results in lower air volume requirements for ventilating tunnels than for buildings.

1. Required Ventilation

A ventilation rate of three cfm per person is sufficient to keep oxygen and carbon dioxide levels adequate for survival. This is the volume which should be used as the basis for estimating the design capacity of a ventilation system for a tunnel. The volume of ventilation that is required in a building occupied at 10 square feet per person to keep the effective temperature within tolerable limits ranges from 5 to 50 cfm per occupant, depending on the geographic location. At either ventilation rate, proper distribution of the ventilating air is required in order to achieve the stated goals. It is important, therefore, that an effort be made to achieve a uniform distribution of the air over the shelter area.

2. Existing Ventilation Systems

As can be seen in Table 3, the four building codes referenced are consistent in requiring either windows with an aggregate openable area not less than one twentieth the floor area served as a source of natural ventilation or a means of providing equivalent mechanical ventilation. The National Building Code (Ref. 1) through a reference to the ASHRAE Applications Handbook (Ref. 5) gives the most detailed and widely applicable guidelines of the four building codes for mechanical ventilation rates in the various use classes. In comparing the ventilation rates (recommended by the National Building Code as displayed in Table 3) to the required fallout shelter ventilation rate of 5 to 50 cfm per space (10 square feet), it is apparent that buildings in some use classes have the potential of offering adequate existing ventilation. The religious or amusement/meeting use classes call for mechanical ventilation rates of from 5 to 15 cfm of outside air per 10 square feet. The industrial use class

calls for from 15 to 30 cfm of outside air per 10 square feet. Based on these requirements, industrial buildings (which comprise 7.4 percent of the four-county host area sample) should contain mechanical ventilation systems of sufficient capacity to support the fallout shelter populations in most parts of the country. Religious and amusement/meeting buildings (which comprise 4.5 percent of the four-county host area sample) are expected to have adequate mechanical ventilation systems in some parts of the country, with the likelihood being higher in buildings in which smoking is allowed. From Table 3, it appears unlikely that buildings in the other use classes contain adequate mechanical ventilation systems. However, most mechanical ventilation systems are equipped with dampers that limit the volume of outside air entering the facility such that the air circulated through a building is approximately 25 percent outside air and 75 percent recirculated air. In these cases, if the damper is opened to permit 100 percent outside air, the volume of outside air provided increases by a factor of four. Referring again to Table 3, it can be seen that, when the rates recommended by the National Building Code are multiplied by four, the ventilation volume should be adequate for the shelter population in most use classes in most parts of the country (except for stores under use class 50 and the additional possible exceptions of use class 10, and offices under use classes 40 and 50).

3. Provision of Ventilation

As was the case with lighting, if existing mechanical ventilation systems are to be utilized during a shelter stay, they must be connected to emergency power sources. It is pointed out in the lighting section that, in the four-county host area sample, approximately 25 percent of the buildings in the government services and industrial use classes were found to be equipped with emergency generators. Since industrial buildings are also indicated above as likely to contain adequate mechanical ventilation systems, it is possible that everything that is needed to ventilate some industrial buildings in a crisis situation is located on-site. However, this is almost certainly not the case with buildings in the other use classes, and portable engine-generators would have to be used in such cases. Appendix C identifies factors which should be taken into consideration in utilizing an engine-generator in an existing building and presents guidelines for connecting an engine-generator into the electrical distribution system of a building.

In a building in which the existing mechanical ventilation system is inadequate or in which no mechanical system has been installed, provisions should be made for furnishing forced ventilation during a shelter period. It does not appear to be practical to try to augment an existing mechanical ventilation system of insufficient capacity. It is generally easier to design an expedient system to supply all of the required ventilation rather than to perform the detailed analysis of the existing system.

In a recent experimental program which RTI conducted (Ref. 8) for DCPA, it was concluded that Kearny pumps are not a very reliable means of supplying forced ventilation because outside air currents drastically reduce their effectiveness. Further experiments performed by RTI (Ref. 9) involving the installation of a ventilation system in a mine, have shown that industrial-type fans powered by emergency engine-generators are relatively easy to install and are very effective in ventilating large shelters.

According to the four building codes referenced in Section III, buildings in all use classes are expected to have enough openable window area to serve as air supply and exhaust openings for forced ventilation systems. During development of host area plans, air inlet and exhaust openings should be identified and should be located so that air will be distributed through as much of the building as possible. It will be most helpful if an engineer or technician experienced in the design and installation of mechanical ventilation systems is consulted at this stage of the planning effort. If industrial-type fans are to be used for shelter ventilation, surveys will be needed during the planning stage to locate sources of both fans and engine-generators, and arrangements for the use and transportation of the equipment in the event of an emergency will be required. RTI's Mine Utilization in Crises - Planning Manual (Ref. 7) provides guidance for installing fans and engine-generators in a mine and covers factors that are also applicable to buildings. Kearny pumps may be used to distribute air within buildings to rooms or areas within rooms that otherwise do not receive ventilation. Identification of sources of materials with which to construct these devices should also be accomplished during the planning stages.

A highway tunnel is physically similar to an open stope mine in which the usable floor area is located in the haulage drifts. In the previous work cited above (Ref. 7), RTI developed detailed instructions covering the

planning and installation of mechanical ventilation systems in such mines. These instructions are equally applicable to tunnels and should be consulted for guidance in planning ventilation systems for tunnels.

C. Water Supply

One of the essential elements in surviving an extended shelter stay is the provision of clean, safe water. While people can survive for extended periods (two or more weeks) without food, just a few days (two or three) without water can produce either serious physiological consequences or death. Water is especially critical to life support in a hot environment.

The need for an adequate water supply in a shelter during a nuclear crisis is obvious and must be met to ensure the welfare of the sheltered population. This need, as related to shelter facilities, is discussed herein, and includes descriptions of different types of facilities, per capita water requirements, means of augmenting water supplies in shelters, and guidance on water disinfection.

1. Water Supply Requirements

Per capita water requirements in the literature vary widely according to the authority and to the types of conditions as shown in Table 9. Part of the variation in requirements is due to environmental factors, such as Assar's recommendation of 0.8 to 1.6 gal (3 to 6ℓ) with the lower figure being for temperate regions and the higher, for arid regions (Ref. 10). Chanlett's figure of 2.5 gal (9.5ℓ) for U.S. drinking water includes, in addition to the water ingested, all water lost in the process of drinking, such as the water lost down the drain when getting a glass of water (Ref. 11). Other volume differences are due to usage conditions with more water needed for such activities as mass feeding and hospital services. The recommendation by Wright, et al., of 0.3 to 5.3 gal (1 to 20ℓ) is a range indicating per capita water requirements for strictly personal needs (Ref. 7). Muhler's figure is based on the pysiological need of 1 ml of water per calorie of food ingested (Ref. 12). FCDG and DCPA recommendations assume that more water will be available to the fallout shelter population three days after nuclear attack (Refs. 13 and 14). Other factors influencing water requirements include age, health, sex, and physical condition (e.g., pregnancy).

In light of the data presented above, great difficulty arises in selecting a specific volume of water needed per person in shelter conditions. Perhaps the most feasible approach is to select a range of values as

Table 9. Daily Per Capita Water Requirements

Source	Volume gal(ℓ)/person/day	Conditions
Muhler 1/	0.7 (2.5)	1 ml of water for each calorie of food ingested
Chanlett 2/	2.5 (9.5)	U.S. drinking water usage
FCDG 3/ & DCPA 4/	0.5 (2)	Recommends 3.5 gal per shelter occupant; average shelter stay is 7 days. (3.5 gal x $\frac{4\text{ qt}}{\text{gal}}$ ÷ 7 days = 2 qt/day)
Assar 5/	0.8 - 1.6 (3-6)	During movement of people to temporary shelters in temperate-arid conditions.
Ibid.	4 - 5.3 (15-20)	For drinking, cooking, and basic cleanliness in temporary shelters.
Ibid.	5.3 - 7.9 (20-30)	Same as above, plus mass feeding.
Ibid.	10.6 - 15.9 (40-60)	Same as above, plus hospital and first aid services.
PHS 6/	1 (4)	During movement of people.
Ibid.	0.25 - 1 (1-4)	In temporary shelters.
Ibid.	15 (57)	Mass-feeding operation.
Ibid.	10 - 25 (38-95)	Medical and first-aid.
Wright, et al. 7/	0.3 - 5.3 (1-20)	Potable water for each shelter occupant in mines.

1/ Ref. 12.
2/ Ref. 11.
3/ Ref. 13.
4/ Ref. 14.
5/ Ref. 10.
6/ An Outline Guide Covering Sanitation Aspects of Mass Evacuation, Division of Sanitary Engineering Services, Public Health Service, U.S. Dept. of Health, Education, and Welfare, 1956.
7/ Ref. 7.

suggested by Wright, et al. Therefore, in planning for a sheltered population, a minimum of 0.3 gal (1ℓ) and as close to 5.3 gal (20ℓ) of potable water should be provided for each sheltered person. Selection of these figures, however, does not imply that the other figures are incorrect, but rather it provides some guidelines for the necessary water supply in shelters.

In addition to an adequate water supply, provisions must be made for water distribution in shelters. Based on data presented in Table 10, one watering point (e.g., faucet in piped water supply, or tap in water tank) should be provided for each 100 persons. Again, as with per capita water requirements, selection of this figure does not imply that others are incorrect, but rather serves as a guideline. Also, watering points should be distributed throughout the shelter, and not concentrated in a single, or a few, location(s). For example, if 25 watering points are located at one end of a warehouse sheltering 2,500 people, many of the shelter occupants are going to be at a definite disadvantage in obtaining water. Assar recommends that the required walking distance should not be more than 109 yd (100 m) to draw water (Ref. 10).

2. Existing Water Service in Shelter Facilities

As shown previously, nearly all (99.4 percent) of the large shelter facilities in RTI's analysis had a water supply (see Table 5), and 9 percent had water supplied by wells, which may or may not be protected from radioactive fallout. Among the use classes, educational facilities had by far the greatest percentage (24.5) of facilities with wells. Four use classes--residential, religious, government and public services, and transportation--had no wells. The significance of wells is that they may provide a sizeable volume of potable water if they are not contaminated with radioactive fallout, and they are less likely to be distrupted after attack than a community water service. If the well is contaminated, well water could still possibly be available for other purposes such as flushing commodes. Wells, if properly enclosed, are not likely to become contaminated, and hence, they should be protected before fallout begins accumulating to ensure a safe source of water.

3. Water Supply Provision

Most buildings are supplied with public water service that may or may not be potable, or obtainable, through the conventional water system following a nuclear attack. The availability of potable water after attack

Table 10. Watering Points for Large Numbers of People

Source	Watering Points Per Number of People	Conditions
Ehlers and Steel 1/	1:75-100	Types and numbers of plumbing fixtures depends on type of occupancy and number of persons to be served, e.g., schools, factories, warehouses.
OSHA 2/	1:100	In temporary labor camps, one or more drinking fountains will be provided for each 100 occupants or fraction thereof.
Wright, *et al*. 3/	1:50	In mine shelters with crowding.

1/ V. M. Ehlers and E. W. Steel, Municipal and Rural Sanitation, 6th edition, McGraw-Hill Book Co., New York, 1965.
2/ General Industry Standards, OSHA 2206, 29 CFR 1910, OSHA, U.S. Dept. of Labor, January 1976.
3/ Ref. 7.

through the conventional system depends on many factors, such as extent of direct weapons effects, water treatment operations, water contamination, and availability and type of power used to pressurize the system. Even if the water supply system is intact and operational, the system may not be adequate to service a large, sheltered population. Thus, to provide an adequate water supply in buildings used as shelters, services other than the existing water supply system will likely be needed. This supply is, of course, primarily dependent on individual, on-site considerations for each shelter.

In determining water augmentation requirements, an assessment should be performed of the probable onsite, postattack water supply. For instance, the following questions should be addressed:

- Is the shelter supplied with a protected well?
- What is the capacity of the well?
- Are pumps, pipes, generators, etc. available to obtain water from the well?
- Is the equipment available to distribute water inside the shelter from a well, tank, or other water source?
- If the shelter is serviced by a public water supply, will this source be available in the postattack environment?
- Is the public water supply from a well, surface water reservoir, or other source?
- Is this source likely to be contaminated from fallout or other factors?
- Will the water treatment plant be operable postattack?
- Is the water supply system located in a high-risk area likely to have direct weapons effects upon water tanks, water pipes, and power?

These are just some of the factors to consider in planning for adequate shelter water supply.

It is possible that water augmentation is needed in a shelter with large masses of people, even if the conventional water supply system is functional; however, the civil preparedness planner should not assume that water will be available through the conventional system postattack. How then, can water be obtained in shelters? Several sources may be available within the building itself, such as the following:

- Fire Control Tanks
- Sprinkler Systems
- Hot Water Heaters
- Supply Pipes
- Holding and Gravity Tanks
- Water Closet Flush Tanks
- Air Conditioning or Chilled Water Systems
- Heating Tanks and Systems
- Indoor Swimming Pools
- Hydraulic Elevators Using Water
- Reflector Pools Within Building (Ref. 13)

However, the water quality should be carefully evaluated to make sure the water is safe for human consumption. This can be accomplished by means recommended by local or state public health departments; therefore, personnel from these departments should be consulted during the shelter implementation planning process.

Other water augmentation possibilities include water stocking in the shelter by using steel drums that have been disinfected (or that have plastic liners). Garbage cans and industrial drums could be used for this purpose, as well as the standard 17-1/2 gallon water drums supplied by DCPA. Tank trucks, such as milk or gasoline trucks, could be cleaned, disinfected, filled with potable water before the attack, and driven to the shelter site. Railroad tank cars could be used in a similar manner where railroad tracks run into, or near buildings such as industrial facilities. Sources of pumps, taps, and pipelines should be located prior to a crisis situation for use with these mobile tanks for distribution within the shelter, and to supply water from a tank parked outside the shelter in the event that sufficient numbers of tanks cannot be moved into the shelter. Great care must be exercised to ensure that all petroleum residues, or other materials, are completely removed from the tanks to prevent the water from being fouled, and to prevent ingestion of toxic substances by the sheltered population.

Water containers can be filled from the individual facility's water service prior to the attack; however, the existing water system must be evaluated to determine if this procedure is feasible. For example, water usage in the host area may be greater than normal prior to the attack due to the filling of water containers by persons in their own homes, but this water demand could be offset by a curtailment of industrial operations that use great volumes of water in their normal manufacturing processes. The season

also has a great influence on the amount of water available in many areas. Thus, preattack water usage in the host area and facility will need to be evaluated individually by civil preparedness planners.

Water supply provision for those persons sheltered in tunnels presents a more complicated problem than for persons in large building facilities. For instance, conventional water facilities will not be generally available in tunnels to fill shelter water containers before the attack. Also, distribution of water in the tunnel shelter is more difficult due to the long, narrow nature of tunnels. As described above, portable containers such as steel drums and tank trucks offer the most feasible method of supplying water to persons in shelters. The logistics of supplying water in tunnels is, however, more complicated than in large buildings due to the structure of the tunnel, its location, and lack of existing water facilities.

4. <u>Water Disinfection Guidelines</u>

Truck and railroad tank cars, wells, and other shelter water storage containers and sources will need to be disinfected to prevent contamination of the water supply. Boiling water before drinking is one means of disinfecting water, but this method may be neither feasible, nor advisable, due to fire hazards and ventilation restrictions in the shelter. Chlorine compounds, e.g. chlorine bleach such as "Chlorox," and other disinfectants are readily available in most areas, and can effectively disinfect water containers and purify water for drinking. Tables 11 and 12 show the amounts of chemicals needed to sterilize water containers and disinfectant water for drinking purposes.

Table 11. Amounts of Chemicals Required for a Strong Chlorine Solution* to Sterilize Wells, Reservoirs, Tankers, etc., Prior to Bringing them into Service 1/

Water		Bleaching Powder (25-30%)		High Strength (70%) Calcium Hypochlorite		Liquid Bleach (5% Sodium Hypochlorite	
Gal.	M^3	Lbs.	G.	Lbs.	G.	Fl.Oz.	ml
26.4	0.10	.022	10	.009	4.3	2.03	60
31.7	0.12	.026	12	.011	5.2	2.43	72
39.6	0.15	.033	15	.014	6.5	3.04	90
52.8	0.20	.044	20	.019	8.5	4.06	120
66.0	0.25	.055	25	.024	11.0	5.07	150
79.3	0.30	.066	30	.029	13.0	6.08	180
105.7	0.40	.088	40	.037	17.0	8.11	240
132.1	0.50	.110	50	.049	22.0	10.14	300
158.5	0.60	.132	60	.057	26.0	12.17	360
184.9	0.70	.154	70	.066	30.0	14.20	420
211.3	0.80	.176	80	.075	34.0	16.23	480
264.2	1.00	.220	100	.095	43.0	20.28	600
317.0	1.20	.265	120	.115	52.0	24.34	720
396.3	1.50	.331	150	.143	65.0	30.42	900
528.3	2.00	.441	200	.190	86.0	40.57	1200
660.4	2.50	.551	250	.243	110.0	50.71	1500
792.5	3.00	.661	300	.287	130.0	60.85	1800
1057.0	4.00	.882	400	.375	170.0	81.13	2400
1321.0	5.00	1.102	500	.485	220.0	101.41	3000
1585.0	6.00	1.323	600	.573	260.0	121.70	3600
1849.0	7.00	1.543	700	[illegible]	300.0	141.98	4200
2113.0	8.00	1.764	800	[illegible]	340.0	162.26	4800
2642.0	10.00	2.205	1000	.948	430.0	202.80	6000
3170.0	12.00	2.646	1200	1.146	520.0	243.33	7200
3963.0	15.00	3.307	1500	1.433	650.0	304.24	9000
5283.0	20.00	4.409	2000	1.896	860.0	405.66	12000
7925.0	30.00	6.614	3000	2.866	1300.0	608.49	18000
10567.0	40.00	8.818	4000	3.748	1700.0	811.31	24000
13208.0	50.00	11.023	5000	4.850	2200.0	1014.14	30000
15850.0	60.00	13.228	6000	5.732	2600.0		
18492.0	70.00	15.432	7000	6.614	3000.0		
21134.0	80.00	17.637	8000	7.496	3400.0		
26417.0	100.00	22.046	10000	9.480	4300.0		
31700.0	120.00	26.455	12000	11.464	5200.0		
39626.0	150.00	33.069	15000	14.330	6500.0		
52834.0	200.00	44.092	20000	19.360	8600.0		
66042.0	250.00	55.115	25000	24.251	11000.0		
79251.0	300.00	66.139	30000	28.660	13000.0		
105668.0	400.00	88.184	40000	37.478	17000.0		
132085.0	500.00	110.230	50000	48.501	22000.0		

*Approximately 30 mg of applied chlorine per litre of water. This is not suitable for drinking purposes.

Instructions for chlorinating with strong chlorine solutions

(1) Stop supplying the public with water from the source (well, reservoir, etc.) that is to be disinfected. For reservoirs and tankers, clean the inside thoroughly by brushing and flushing.

(2) Use one of the chemicals listed in the table. The amount of chemical should correspond to the maximum capacity of the reservoir (tanker).

(3) First dissolve the chemicals in a bucket (not more than about .22 lb (100 g) of calcium hypochlorite or bleaching powder in one bucket of water).

(4) For wells, pour the solution (one or more bucketsful one after another) into the well. If possible, agitate the water to ensure good mixing. For reservoirs and tankers, pour the solution into the tank when it is half full of water and top it up competely afterwards.

(5) Leave the strongly chlorinated water for at least 12 hours in the well or tank. This water should not be used for drinking purposes.

(6) For wells, pump the strongly chlorinated water from the well and reject it until the residual chlorine level is below .0000058 lb per gallon (0.7 mg per litre) of water. For tanks, empty the tank completely and let the water run to waste. Then restart normal operations and supply the public.

1/ S. Rajagopalau and M. A. Shiffman, Guide to Simple Sanitary Measures for the Control of Enteric Diseases. Geneva: World Health Organization, 1974.

Table 12. Amounts of Chemicals Needed to Disinfect Water for Drinking* 1/

Water		Bleaching Powder (25-30%)		High Strength(70%) Calcium Hypochlorite		Liquid Bleach (5% Sodium Hypochlorite)	
Gal.	M^3	Lbs.	G	Lbs.	G	Fl. Oz.	ml
264.2	1.0			.0022	1.0	.47	14
317.0	1.2			.0026	1.2	.57	17
396.3	1.5	.008	3.5	.0033	1.5	.71	21
528.3	2.0	.011	5.0	.0044	2.0	.95	28
660.4	2.5	.013	6.0	.0055	2.5	1.18	35
792.5	3.0	.015	7.0	.0066	3.0	1.42	42
1057.0	4.0	.020	9.0	.0088	4.0	1.89	56
1321.0	5.0	.026	12.0	.0110	5.0	2.37	70
1585.0	6.0	.031	14.0	.0132	6.0	2.84	84
1849.0	7.0	.035	16.0	.0154	7.0	3.31	98
2113.0	8.0	.042	19.0	.0176	8.0	3.72	110
2642.0	10.0	.051	23.0	.0220	10.0	4.73	140
3170.0	12.0	.062	28.0	.0265	12.0	5.75	170
3963.0	15.0	.077	35.0	.0331	15.0	7.10	210
5283.0	20.0	.110	50.0	.0441	20.0	9.46	280
7925.0	30.0	.154	70.0	.0661	30.0	14.20	420
10567.0	40.0	.198	90.0	.0882	40.0	18.93	560
13208.0	50.0	.265	120.0	.1102	50.0	23.66	700
15850.0	60.0	.309	140.0	.1323	60.0	28.39	840
18492.0	70.0	.353	160.0	.1543	70.0	33.12	980
21134.0	80.0	.419	190.0	.1764	80.0	37.18	1100
26417.0	100.0	.507	230.0	.2205	100.0	47.32	1400
31700.0	120.0	.617	280.0	.2646	120.0	57.46	1700
39626.0	150.0	.772	350.0	.3307	150.0	70.98	2100
52834.0	200.0	1.036	470.0	.4409	200.0	94.64	2800
66042.0	250.0	1.279	580.0	.5512	250.0	118.30	3500
79251.0	300.0	1.543	700.0	.6614	300.0	141.95	4200
105668.0	400.0	2.072	940.0	.8818	400.0	189.28	5600
132085.0	500.0	2.579	1170.0	1.1023	500.0	236.60	7000

*Approximate dose = .0000058 lb of applied chlorine per gallon (.7 mg per litre) of water.

<u>Instructions for chlorinating drinking water</u>

(1) Use one of the chemicals listed in the table and choose the amount according to the quantity of water in the distribution tank, cistern, or tanker.

(2) Dissolve the chemicals first in a bucket of water (not more than about 100 g of calcium hypochlorite or bleaching powder in one bucket of water) and pour the solution into the tank. If possible, agitate the water to ensure good mixing.

(3) This chlorination procedure should be repeated as soon as the level of residual chlorine in the water drops below .0000017 lb per gallon (0.2 mg per litre).

1/ S. Rajagopalau and M. A. Shiffman, Guide to Simple Sanitary Measures for the Control of Enteric Diseases. Geneva: World Health Organization, 1974.

D. Excreta Disposal

Sanitary sewage disposal is another important aspect of utilizing large buildings as shelters. Without proper sewage management, contamination of food and water, creation of a noxious environment due to excreta smell and sight, and harborage of pathogenic organisms can result. Under such circumstances, disease outbreaks are likely to occur within the sheltered population.

1. Sewage Disposal Requirements

Many factors influence individual excreta production, including water intake, diet, health, age, and sex. Normally, the excreta loss in humans is directly related to water intake; that is, excreta loss equals water intake and *in vivo* water production. Hence, excreta produced in a sheltered population is directly related to, and could be somewhat controlled by, per capita water intake.

Excreta loss occurs by four mechanisms: urine, feces, sweat, and insensible loss (skin evaporation, breath). Values for these water losses from several different sources are shown in Table 13. Obviously, urine and feces disposal present the most significant problem. Hereafter, to avoid confusion with total water loss by excretion, urine and feces will be referred to as sewage.

For the purposes of this report, per capita sewage production is assumed to be 42 oz/day (1,200 ml/day) urine and 3 oz/day (90 ml/day) feces based on figures for the standard adult man and adult woman (Ref. 15). Thus, the daily per capita sewage production is determined to be 45 oz.(1,290 ml). Although 45 oz.(1,290 ml) is selected, this does not mean that other figures ranging from about 35 oz.(1,000 ml) to 56 oz.(1,600 ml) would be incorrect, but rather that 45 oz.(1,290 ml) is one of a number of acceptable values that could have been selected. Using 45 oz.(1,290 ml) then, gives neither exact, minimum, or maximum determinations, but does give realistic approximations of the desired disposal capacity.

DCPA recommends 1 toilet per 50 shelter occupants. While this figure is probably adequate for shelter provisioning, a more desirable figure is 7 toilets per 100 shelter occupants. For the purposes of this report, 1 toilet/50 shelter occupants is used in quantifying requirements (Refs. 7, 14, and 16).

2. Existing Sewage Disposal Facilities

The basic problem of sewage disposal in a large shelter stems from the fact that most facilities have not been originally constructed to

Table 13. Daily Water (Excreta) Loss in Humans (ml/day)

Source		Urine	Feces	Sweat	Insensible Loss	Total Water Losses
Radiological Health 1/ (ml/day)	Adult Man	1,400(49)	100(4)	650(23)	850(30)	3,000(10)
	Adult Woman	1,000(35)	80(3)	420(15)	600(21)	2,100(74)
	Child(10 yrs)	1,000(35)	70(2)	350(12)	580)20)	2,000(70)
Ehlers and Steel 2/ (g)		970(34)	83(3)	---	---	---
Vander, et al. 3/ (ml water)		1,500(53)	100(4)*	50(2)	900(32)	2,550(8)
Parker and West 4/ (lbs converted to g)		1,560(55)	122(4)	934(33)	907(32)	---
Chanlett 5/(g)		---	100-150(4-5)	---	---	---
Wright, et al. 6/ (oz. converted to g)		---	---	---	---	2,400(84)
DCPA 7/ (estimated disposal; gal converted to ml)		1,830		---	---	---

NOTES: * Total daily fecal elimination is 50g - 100g water and 50g solid matter.

Numbers in parentheses are the equivalent amounts in ounces.

g(grams) is equivalent to ml (milliliters)

1/ Ref. 15.

2/ V. M. Ehlers and E. W. Steel, Municipal and Rural Sanitation, 6th edition, McGraw-Hill Book Company, New York, 1965.

3/ A. J. Vander, J. H. Sherman, and D. S. Luciano, Human Physiology, McGraw-Hill Book Company, New York, 1970.

4/ J. F. Parker, Jr., and V. R. West, Bioastronautics Data Book, 2nd edition, NASA SP-3006, Scientific and Technical Information Office, National Aeronautics and Space Administration, Washington, D. C., 1973.

5/ Ref. 11.

6/ Ref. 7.

7/ Ref. 14.

accommodate large numbers of densely concentrated people for an extended period of time. There are, however, widely varying degrees to which a shelter facility must be upgraded for crisis relocation, depending primarily on the present usage of the facility. Table 5 shows that, on the average, there is a deficit of 13.6 commodes per 1,000 people in host-area shelter facilities. However, there are wide variations among the use classes, ranging from a deficit of only 3.2 commodes per 1,000 people in residential buildings to a deficit of 19 commodes per 1,000 people in transportation facilities. Of course the use of the existing sewage disposal facilities is dependent on the availability of water during a crisis situation. Therefore, the usefulness of existing facilities, and thus, the upgrading required for each shelter facility for proper sewage disposal, must be considered individually by the local civil preparedness planner.

3. Determination of Shelter Sewage Capacity

The Federal Civil Defense Guide (FCDG) calls for 2.1 gallons (gal), 8ℓ, of human waste disposal capacity for each person sheltered (Ref. 13). That document also predicts shelter occupancy periods (following a heavy nuclear attack upon counterforce, industrial, and population objectives) as follows:

- 2 days in about 25 percent of the Nation's area.
- 2 days to 2 weeks in about 50 percent of the Nation's area.
- 2 weeks in the remaining 25 percent of the Nation's area (Ref. 17).

This prediction, however, does not account for shelter periods of a relocated population, and hence, presents the extreme scenario of in-shelter periods. With the implementation of population relocation plans, in-shelter periods should be reduced.

Considering the above information, FCDG recommendations for sewage disposal capacity may or may not be adequate. With a per capita disposal capacity of 2.1 gal (270 oz or 8ℓ) and per capita daily sewage production of 45 oz (1,290 ml), adequate sewage disposal capacity is provided for only 6 days (270 oz ÷ 45 oz/day = 6 days). This disposal capacity is adequate for approximately 50 percent of the sheltered population, assuming an average in-shelter stay of 1 week and no population relocation. To provide adequate shelter disposal capacity for a 2-week shelter period, 4.9 gal, or 18.5ℓ

(Ref. 10) (45 oz/day x 14 days = 630 oz at 128 oz/gal = 4.9 gal) of sewage disposal capacity must be provided for each sheltered person.

Another DCPA document, the DCPA Attack Environment Manual (Ref. 14), recommends a sewage disposal capacity capable of handling 0.5 gal (2 ℓ) of sewage/day. This same document also reveals that, when water intake is restricted, healthy human bodies compensate by reducing urine excretion by half, to about 1.5 pints (24 oz, or 0.690 ℓ). Based on the previous data, the 0.5 gal (2 ℓ)/day capacity is assumed to be the maximum.

With the above figures in mind, the following recommendations are made concerning the provision of fallout shelter sewage disposal capacity:

	Minimum*	Norm	Maximum**
Human Waste Disposal Capacity in gal/day (l/day)	0.15(0.6) (2.1 gal ÷ 14 days = .15 gal/day)	0.35(1.3) (4.9 gal ÷ 14 days = .35 gal/day)	0.5(2)

* Based on the Federal Civil Defense Guide recommendations.

** Based on the DCPA Attack Environment Manual recommendations.

While these recommendations are intended to provide guidelines for human sewage disposal capacity, other liquid and semi-solid wastes, such as wastewater from cooking and sewage from pet dogs and cats, may also be added to the shelter sewage disposal system. With this in mind, the shelter sewage disposal system capacity should not, if possible, be determined on the basis of the minimum figure.

4. Methods of Shelter Sewage Disposal

Once the necessary degree of upgrading for sewage disposal has been determined, provisions must be made to supply the needed materials and equipment to develop the needed disposal capacity. The provisions, however, will vary greatly according to the type of facility being upgraded, and hence, each facility will need to be considered individually as to the most effective means of meeting the demands for sewage disposal. Certain methods and considerations which can be applied generally to any facility are discussed in this section.

Ideally, a shelter will have a sufficient number of flush toilets to accommodate the sheltered persons, and the water supply will not be adversely affected by the nuclear attack so that the toilets can be used. Practically, alternative methods of sewage disposal should be planned for as contingencies because: (1) the existing toilets may not be usable following the attack; and (2) the existing toilets, if usable, will probably not provide adequate sewage disposal capacity in most shelters. Hence, a method, or methods, of sewage disposal should be selected for a fallout shelter facility, and planned and implemented with the following criteria in mind:

> In general, any method of excreta disposal that is considered should confine excreta; prevent contamination of water supply; provide convenience and privacy; and be clean and relatively odor free. From a practical standpoint, the disposal method chosen should be simply and quickly constructed, easily maintained, operable with a minimum reliance on the individual user, reliable over an extended period of time, and utilize resources in a cost-effective manner. (Ref. 7)

Various alternatives to a water-borne sewage disposal system, which can be adapted to meet the above criteria, are shown in Table 14.

Inside a shelter facility, the most feasible auxiliary sewage disposal methods are those that are self-contained, such as chemical toilets and removable pail privies. The feasibility of using disposal methods that require soil is low since most of the facilities will probably have a thick concrete slab that serves as, or underlies, the floor. Not to be discounted is the use of existing toilets that would provide significant sewage disposal capacity as long as sufficient water is used to flush excreta and other semi-solid wastes. Even if the water supply is contaminated with fallout and is nonpotable, flush toilets can be used as normal provided that the water supply system remains intact and operable following nuclear attack. This use depends upon many factors, such as reserve water supply, maintenance of power, and gravity feed.

Table 14. Sanitary Excreta Disposal Methods

FACILITY	SUITABILITY	LOCATION	CONSTRUCTION	MAINTENANCE
Sanitary earth pit privy	Where soil available and ground-water not encountered. Earth can be mounded up if necessary to bring bottom of pit 2 ft above groundwater or rock.	Downgrade, 100 ft or more from sources of water supply; 100 ft from kitchens; 50 to 150 ft of users; at least 2 ft above ground-water; 50 ft from lake, stream.	Deep pit; insects, rodents, and animals excluded; surface water drained away; cleanable material; attractive; ventilated pit and building. Pit 3'×4'×6' deep serves average family 3 to 5 yr.	Keep clean and fly-tight; supply toilet paper. Apply residual fly spray to structure and borax, fuel oil, or kerosene to pit. Natural decay and desiccation of feces reduce odors. Keep waste water out. Scrub seat with hot water and detergent.
Excreta disposal pit	For disposal of pail privy and chemical toilet contents.	Downgrade and 200 ft from sources of water supply; 100 ft from kitchen.	Shored pit with open-joint material. Tight top and access door.	Keep fly-tight and clean. Drain surface water away.
Chemical toilet (cabinet and tank-type)	A temporary facility. To protect water supply, where other method impractical. Temporary camp, vehicle, boat.	May adjoin main dwelling. Tank type same as masonry vault privy.	Same as masonry vault privy. Tank may be heavy gauge metal with protective coating. Provide capacity of 125 to 250 gal per seat.	Use ¼ lb lye for each ft^3 of vault capacity made up to 6" liquid depth in vault, or 25 lb caustic per seat in 15 gal water. Keep clean. Clean vault when 2/3 to 3/4 full. Odor control. Empty and recharge as directed.
Removable pail privy (bucket latrine)	A temporary facility; to protect water supply, where pit privy impractical.	Same as masonry vault privy.	Same as masonry vault privy. Provide easily cleaned pails.	Provide collection service, excreta disposal pit, and cleaning facilities, including hot water (backflow preventer), long-handled brushes, detergent, drained concrete floor.
Portable box, earth pit, latrine	At temporary camps.	Same as pit privy. Army recommends latrine 100 yd from kitchens.	Earth pit with portable prefabricated box.	Same as earth pit privy. Provide can cover to keep toilet tissue dry.
Bored-hole latrine	In isolated place or when primitive, inexpensive, sanitary facility is needed.	Same as earth pit privy.	Bored hole 14 to 18" diameter and 15 to 25 ft deep with bracing if necessary. Seat structure may be oil drum, box, cement or clay tile riser with seat, or use squatting plate. Platform around hole.	Same as earth pit privy. Line upper 2 ft of hole; in a caving formation line hole to support earth walls.
Straddle trench latrine	At temporary camp for less than one day.	Same as earth pit privy.	Trench 1 ft wide, 2½ ft deep, and 4 ft long for 25 men.	Frequent inspection. Keep excreta covered. Provide toilet paper with waterproof cover.
Cat hole	On hikes or in field.	Same as earth pit privy.	Hole about 1 ft deep.	Carefully cover hole with earth.
Squatting latrine	Where local conditions and customs permit.	Same as pit privy.	Similar to privy or bored-hole latrine.	Same as privies and latrines.

Note: If privy seat is removable and an extra set is provided, it is easier to scrub seats and set aside to dry. A commercial plastic or composition-type seat is recommended in place of improvised crudely made wooden seats. Deodorants that can be used if needed include chlorinated lime, cloroben, iron sulphate, copperas, activated carbon, and pine oil. Keep privy pits dry. Solutions for chemical toilets include lye (potassium hydroxide), caustic soda or potash (sodium hydroxide), chlorinated lime (1 lb in 2½ gal water), copper sulfate (1 lb in 2½ gal water), and a chlorinated benzene.

Source: Salvato, Joseph A., Jr., Environmental Engineering and Sanitation, Second Edition, New York: Wiley-Interscience, 1972.

Due to the likelihood that shelter occupants might be able to leave the shelter for brief periods of time soon after nuclear attack, sewage disposal facilities that are located outside the shelter may be feasible. This alternative could be constructed by using heavy construction equipment, such as bulldozers and backhoes, to dig trenches for waste disposal. Toilet seats could then be built over the trenches forming a large sanitary earth pit privy. Trenches could be used to dump sewage collected from pail privies inside the shelter, and for solid waste disposal. In shelter facilities which are upgraded by piling earth against exterior walls and on the roof to provide adequate fallout protection, the earth could be obtained by digging trenches during the upgrading process. Of course, great care must be exercised in using heavy construction equipment to dig large trenches so that underground electricity, gas, sewage, and water lines will not be disrupted. Another alternative could be the use of sewer lines near the shelter which are accessible by manholes. By removing the manhole cover, a voluminous area will be exposed that is desirable for sewage and waste disposal. Still another alternative may be to run pipelines from inside the shelter to a large trench or sewer and pump sewage and other liquid wastes into the trench from collection areas (e.g.,sumps, railroad tank cars, tank trucks, chemical or food vats) inside the shelter. However, careful planning is needed in the use of trenches for sewage disposal to prevent contamination of ground water that is to be used as a source of drinking water.

The limiting factors of extraneous shelter sewage disposal are the availability of open space (preferably unpaved) outside the facility and the existing radiation levels. The former will have to be considered on an individual shelter basis prior to implementation; the latter is also an individual shelter consideration to be determined after the attack by shelter managers using approved radiation-measuring equipment. Table 15 shows general estimates of the consequences of radiation expected from short-term external gamma radiation dose or an equivalent residual dose (ERD) that has not exceeded 200 r (roentgen). The table indicates that exposures to levels below 200 r generally do not require medical attention; exposures below 50 r are probably acceptable for shelter occupants going outside the shelter for brief periods. Thus, with careful control, radiation levels can be monitored to limit radiation exposures so that shelter occupants can go outside the shelter for sanitary reasons, water, and other missions.

Table 15. Estimated Consequences of Short Term External 1/ Gamma Radiation Doses

	Consequences or effects	Short term dose ERD (Equivalent Residual Dose)
(1)	Smallest effect detectable by statistical study of blood counts of a large group of people	15 r
(2)	Smallest effect detectable in an individual by laboratory methods	50 r
(3)	Smallest dose that causes vomiting on day of exposure in at least 10 percent of people	75 r
(4)	Smallest dose that causes epilation (loss of hair) in at least 10 percent	100 r
(5)	Largest dose that does not cause illness severe enough to require medical care in majority of people (more than 9 out of of 10).	200 r
(6)	Dose that would be fatal to about 50 percent of the people	450 r
(7)	Dose that would be fatal to almost everyone	600 r

1/ "RADEF Fundamentals," Part E, Chapter 5, Appendix 1, Federal Civil Defense Guide, Office of Civil Defense, Department of Defense, June 15, 1963.

As was the case with providing water, the management of human excreta in tunnel shelters is more complicated than for large building facilities. Self-contained sewage disposal methods are the most feasible methods within the shelter, but careful planning is needed to provide toilets for the shelter occupants within reasonable walking distances. For instance, toilets placed near the ventilation exhaust to reduce the odor problem may cause some of the shelter occupants to walk considerable distances to the toilets. For practicality in long tunnels, the odor problem will need to be endured to ensure the presence of toilets in the proximity of the entire sheltered population.

Sewage facilities can also be constructed outside the tunnels in non-paved areas (as discussed above for large building facilities). This construction will add additional sewage disposal capacity, but also entail considerable walking distances for some of the shelter occupants. The most convenient method of sewage disposal is a combination of self-contained toilets in the tunnel, especially the middle area, and extraneous toilet facilities constructed just outside the tunnel entrance. Management, supplies, and disinfection requirements are similar to those previously described for buildings.

E. Solid Waste Disposal

In order to maintain a sanitary environment in a shelter, provisions must be made for proper solid waste disposal. Indiscriminate disposal can lead to a variety of problems, including odors, flies, rats, roaches, crickets, wandering dogs and cats, and fires (Ref. 18). The following discussion will deal with factors associated with solid waste production and disposal as related to fallout shelters located in large facilities. Topics to be covered are the composition, per capita production, and disposal methods.

1. Composition and Production

What is solid waste? It might best be defined as solid matter (except human feces) that is generated during the daily activities of man. Some of the kinds of solid waste expected to be generated are shown in Table 16.

Table 16. Examples of Refuse Materials; their Composition and Sources 1/

Kind	Composition	Sources
Garbage	Wastes from preparation, cooking, and serving of food; market wastes; wastes from handling, storage, and sale of produce.	Households, restaurants, institutions, stores, markets.
Rubbish	Combustible: paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, wood furniture, bedding, dunnage.	Same as garbage.
	Noncombustible: metals, tin cans, metal furniture, dirt, glass, crockery, minerals.	
Ashes	Residue from fires used for cooking and heating and from on-site incineration.	Same as garbage.
Industrial wastes	Food-processing wastes, boiler-house cinders, lumber scraps, metal scraps, shavings.	Factories, power plants.
Special wastes	Hazardous solids and liquids: explosives, pathological wastes, radioactive materials.	Households, hotels, hospitals, institutions, stores, industry.
Sewage treatment residue	Solids from coarse screening and from grit chambers; septic-tank sludge.	Sewage treatment plants, septic tanks.

From *Municipal Refuse Disposal*, Institute for Solid Wastes of American Public Works Association and Bureau of Solid Waste Management, Public Administration Service, U.S. Dept. of HEW, Chicago, Illinois, 1970, p. 13.

1/ Ref. 18.

In a shelter situation, the composition of solid waste will differ from that produced during normal daily activities. A large portion of the solid waste generated in shelters is expected to be generated during food preparation and mass feeding operations; hence, the composition will include cans, jars, plastic wrapping, boxes, disposable tableware, plates, trays, and cookware. Personal hygiene practices will also add to solid waste generation. In addition, the possibility and necessity of corpse disposal should not be overlooked.

The per capita solid waste production varies widely due to such factors as season, urban or rural location, and personal factors (such as economic status, education, and social habits). A single numerical value characterizing solid waste production for a theoretical situation is exceedingly difficult to obtain since the actual known production rates vary from community to community, and from situation to situation.

Actual solid waste production figures from several authorities are shown in Table 17; Table 18 shows figures from different sources of production. From these tables, the per capita solid waste production is seen to range from 0.72 lbs (0.3 kg)/day for rural household waste to 8 lbs (4 kg)/day for mixed refuse. The per capita production by source (as seen at the top of Table 18) ranges from 1.5 lbs (0.68 kg)/day at camps to 5.5 lbs (2.49) per capita/day for municipal waste.

Per capita solid waste production in shelters will probably be significantly lower than most of the values indicated in the tables. By habit, most U.S. citizens live in a wasteful manner, and hence, per capita solid waste production and composition would probably be strikingly reduced in a shelter situation where resources are drastically limited. Neither the Federal Civil Defense Guide (Ref. 13) nor the DCPA Attack Environmental Manual (Ref. 14) specifically addresses the production rate of solid wastes in shelters. However, judging from Table 17, the per capita solid waste production during shelter occupation can be assumed to be about 1.5-2.5 lbs/day (.68-1.1 kg day) for planning purposes.

2. Disposal Methods

Several options are available for the disposal of solid waste generated in shelters. Among the options are storage cans and bins, mobile storage containers, incinerators, and trenches. Provisions should be made

Table 17. Daily Per Capita Solid Waste Production

Source	Quantity in pounds (kilograms) per capita per day	Conditions
Ehlers and Steel 1/		
Garbage	0.6 (0.3)	Quantities of expected municipal wastes
Rubbish	0.9 (0.4)	
All Refuse	2.2 (1)	
Chanlett 2/	7 (3)	1968 estimates for household, commercial, and municipal producers based on the U.S. national survey of community solid wastes covering 6,000 communities, 33 states, and representing over one-half of the U.S. population.
PHS 3/	8 (4)*	Average American Community refuse production.
Salvato 4/	7 (3)	Amount of municipal solid waste generated in 1968.
Total		
National Average	5.32 (2.4)	Average per capita solid waste collected in U.S. in 1968.
Household, urban	1.26 (0.6)	
Household, rural	0.72 (0.3)	
Household, national average	1.14 (0.5)	

* Derived from 8 cu.yd/1,000 population/day, assuming mixed refuse weighs 1,000 lb/cu.yd.[3]

1/ Based on 1953 data from V. M. Ehlers and E. W. Steel, Municipal and Rural Sanitation, 6th edition, McGraw-Hill Book Company, New York, 1965.

2/ Ref. 11.

3/ An Outline Guide Covering Sanitation Aspects of Mass Evacuation, PHS Publication No. 498, Div. of Sanitary Engineering Services, Public Health Service, U.S. Dept. of Health, Education, and Welfare, 1956.

4/ Ref. 18.

Table 18. Approximate Solid Waste Production Rates 1/ - Various Sources

Source of Waste	lb per Day
Municipal	5.5 per capita
Household	2.3 per capita, or
	5.0 per capita plus 1 lb per bedroom†
Apartment building‡	4.0 per capita per sleeping room†
Seasonal home	2.5 per capita*
Resort	3.5 per capita*
Camp	1.5 per capita*
Hotel, first class	3.0 per room†
Medium class	1.5 per room†
Motels	2.0 per room†
Day use facility, resort	0.5 per capita*
Trailer camp	6 to 10 per trailer†
Commercial building, office	1.0 per 100 ft^2 †
Department store	40 per 100 ft^2 †
Supermarket	9.0 per 100 ft^2 †
Restaurant	2.0 per meal†
Drugstore	5.0 per 100 ft^2 †
Retail and service facility	13.0 per 1000 ft^2 †
Wholesale and retail facility	1.2 per 1000 ft^2 †
Warehouse	2.0 per 100 ft^2 †
National Forest recreation area§	
Campground	1.26 ± 0.08 per camper
Family picnic area	0.93 ± 0.16 per picnicker
Organized camps	1.81 ± 0.39 per occupant
Rented cabin, with kitchen	1.46 ± 0.31 per occupant
Lodge, without kitchen	0.59 ± 0.64 per occupant
Restaurant	0.71 ± 0.40 per meal served
Overnight lodge, winter sports area	1.87 ± 0.26 per visitor
Day lodge, winter sports area	2.92 ± 0.61 per visitor
Swimming beach	0.04 ± 0.01 per swimmer
Concession stand	0.14 per patron
Job Corps, Civilian Conservation Corps Camp,	
Kitchen Waste	2.44 ± 0.63 per corpsman
Administrative and Dormitory	0.70 ± 0.66 per corpsman

**Environmental Health Practice in Recreational Areas*, U.S. Public Health Service Pub. No. 1195, Dept. of HEW, Washington, D.C., 1965.

†*I.I.A. Incinerator Standards*, Incinerator Institute of America, New York, May 1966. Up to 20-30 lb per bed per day at teaching hospitals, total. Total solid waste production at general hospitals is estimated at 12 to 15 pounds per bed with an average patient occupancy of 80 percent.

‡A study at a low-income high-rise multifamily housing project shows the average daily refuse disposal via trash chutes to be 1.48 lb per capita, or 6.23 lb per dwelling unit, and 5.6 lb/ft^3, not including yard or bulky wastes. R. Barry Ashby, "Experiment in New Haven," *Waste Age* (November-December 1970), p. 22.

§Source: Charles S. Spooner, *Solid Waste Management in Recreational Forest Areas*, U.S. Environmental Protection Agency, Washington, D.C., 1971. Average rate of waste generation 90 percent confidence interval.

1/ Ref. 18.

for sufficient disposal capacity in the shelter to ensure that health hazards will not be created by solid waste, regardless of the method selected.

The method most suitable for short-term stays is the provision of storage cans and bins. Even if another method is chosen, cans and bins will be necessary for temporary holding of solid waste. Waste containers of 26-gal (100ℓ) capacity, or less, should be provided at the rate of 3 or 4 containers per 100 people. These containers should be washable, watertight, and have tight-fitting, overlapping lids (Ref. 10). Plastic liners in the containers would aid in disposal routines and also provide more sanitary conditions by keeping the containers cleaner than those not having liners. Regular galvanized garbage cans for home use are well-suited for this method and should be located conveniently to as many people as is feasible. The cans should also be arranged in groups of about 20 or 30 to expedite emptying and maintenance routines (Ref. 7). Table 19 shows solid waste disposal recommendations from several authorities.

Larger storage containers may be feasible. For instance, containerized trash bins, such as the common Dempster Dumpster, can be provided. In some cases, the dumpster can actually be located inside the shelter and serviced by the dumpster service trucks. In other cases, the dumpster can be located just outside the entrances (preferably not at one of the air-intakes) to serve as a temporary holding vessel for solid waste emptied from smaller containers located within the shelter. (The feasibility of leaving the shelter for short periods of time is discussed in the "Excreta Disposal" section.) Still another method of containerized solid waste disposal is the use of large, mobile containers for temporary storage. Compactor-type garbage trucks would be ideal for this method. Other potential large containers might include railroad cars or tractor-trailers, but these would have to be evaluated for accessibility of solid waste disposal from small containers and for tightness to seal out vermin. These large containers could be located either inside or outside the shelter, depending on individual shelter characteristics. They offer a feasible temporary solution to solid waste storage. After the crisis period, the accumulated solid waste could be disposed of using trenches outside the shelter, available community facilities (e.g., sanitary landfill, incinerator), or other suitable methods.

Table 19. Solid Waste Disposal Capacity Recommendations

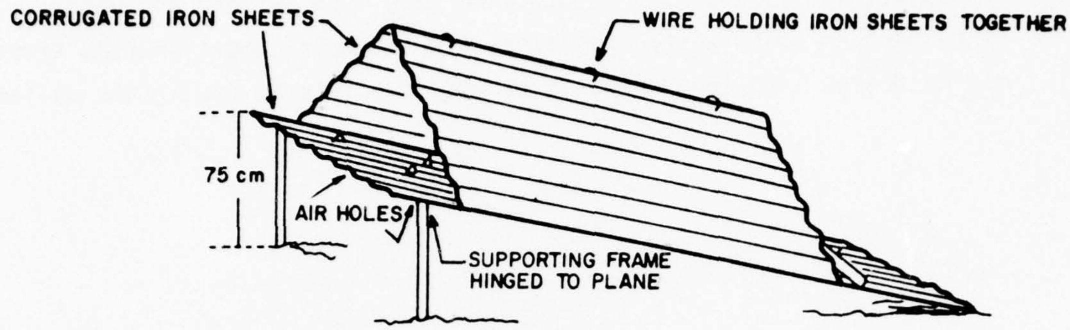
Source	Solid Waste Disposal Capacity
Assar 1/	3-4 containers per 100 people. Capacity of containers should be 26 gal (100 ℓ) or less. They should be washable, watertight, and provided with tight-fitting, overlapping lids. A truck of 13 cu.yd. (10m^3) capacity with a driver and 2 helpers can serve 5000-8000 people by making 3 trips daily to the disposal area.
PHS 2/	A 12 cu.yd. (9 m^3) compactor-type garbage truck with a driver and 2 helpers making 3 trips daily to the disposal point can serve a city of 5000 in peacetime. Compactor trucks are made in 9-, 12-, 16-, and 20-cubic-yard sizes.
Salvato 3/	Watertight, rust-resistant containers with tight-fitting covers of 20- to 32-gal capacity, or up to a 50-gal capacity for rubbish. Use of can liners will simplify collection, and reduce frequency of can cleaning, fly breeding, and odor potential.
Ehlers and Steel 4/	Containers for mixed refuse shall not exceed 30-32 gal (114-122 ℓ) capacity and should have side handles. Containers for garbage, whether separate or with other refuse, should not exceed 12-20 gal (46-76 ℓ) capacity and should have tight-fitting or lock-type covers. They should be made of 26-30 gage galvanized metal, not plastic, to prevent rats from gnawing into the container.

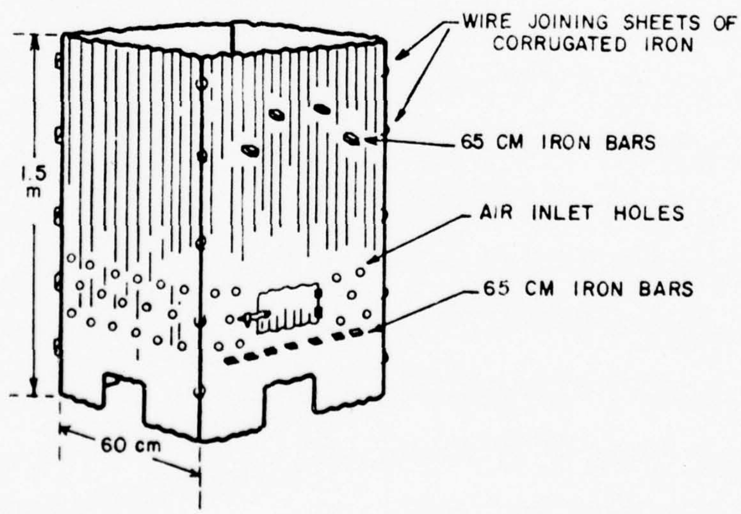
1/ Ref. 10.
2/ An Outline Guide Covering Sanitation Aspects of Mass Evacuation, PHS Publication No. 498, Div. of Sanitary Engineering Services, Public Health Service, U.S. Dept. of Health, Education, and Welfare, 1956.
3/ Ref. 18.
4/ V. M. Ehlers and E. W. Steel, Municipal and Rural Sanitation, 6th edition, McGraw-Hill Book Co., New York, 1965.

Incineration of solid waste is another alternative. Suitable expedient incinerating methods for the shelter are shown in Figure 1. Another type of incinerator is the basket incinerator, which is simply a wire basket standing on stone or metal supports (Ref. 7). Also, some of the facilities may have their own incinerators. If incinerators are used, great care must be excerised to prevent smoke from entering the shelter and to avoid the possibility of asphixiation and accidental incineration, namely, of the shelter itself. Incineration is probably the least desirable waste disposal method for shelter implementation of the methods described in this report.

Burial in trenches, if practical, is a highly recommended method of solid waste disposal for large-facility shelters. This method involves the digging of trenches in open areas adjacent to the shelters by construction equipment, an action very similar to that previously described for human sewage management. Using the burial method, solid waste is periodically collected from small containers inside the shelter and dumped into a trench. Note that acceptable radiation exposures must be determined prior to the emptying of containers outside the shelter by assigned sanitation personnel. After dumping, the solid waste is covered by dirt, either by hand (shovels) or by available earthmoving equipment. This method is adapted after the design of sanitary landfills which are used by many communities for solid waste disposal. As with sewage disposal in trenches, care must be taken to prevent groundwater contamination, especially where wells are used. A big advantage of this method is that relatively little post-shelter operation effort will need to be devoted for sanitary disposal of solid waste since the trench can be covered with dirt in a short amount of time. Also, a trench is likely to be dug if dirt is used to upgrade the facility protection factor (PF). More than likely in the post-shelter environment, the longer the clean-up or disposal time required, the less likely it is to be done, due to emotional factors, and the likelihood of more important tasks that require immediate action.

In the case of tunnels that are utilized as shelters, the long, narrow nature of these facilities complicates solid waste management, especially access to trenches outside the shelter. Solid waste collection barrels, or cans, should be distributed throughout the length of the tunnel. A lane





Source: Assar, M., Guide to Sanitation in Natural Disasters, Geneva: World Health Organization, 1971.

Figure 1. Inclined-Plane Incinerator (top) and Open Corrugated-Iron Incinerator (bottom).

through the tunnel should be kept open at all times for facilitation of solid waste collection, as well as for emergencies, walk-ways for shelter occupants, and transport of other materials such as food and water. Containerized solid waste collectors (for example compactor-type trucks) may be driven into the tunnel at strategic points to facilitate collection.

V. CLOSE-IN SHELTER FOR KEY WORKERS

Under the concept of crisis relocation planning as it is presently envisioned, and in the event of the implementation of population relocation contingency plans, certain key workers would remain near the risk area. These workers could commute to and from their work stations during the time before an attack or if the attack did not occur. Included among the functions that the key workers would perform would be (Ref. 19):

- Police and fire protection to maintain security
- Operation and maintenace of essential utilities
- Operation and maintenance of essential industries (pharmaceutical, food processing, banking, etc.)
- Operation and maintenance of communication systems (telephone, radio, and television)
- Civil defense planning and operations
- Essential transportation functions

Though only essential workers from the organizations performing the above functions would be left behind, these key workers would comprise a group of considerable size for which shelter must be provided. The close-in shelters used by these key workers must be capable of providing protection from blast overpressures ranging from 2 psi to greater than 15 psi; other direct nuclear weapons effects such as thermal pulse; and fallout. Mines, caves, and tunnels would best meet the above criteria, but these facilities are not widely available near risk areas. Buildings that are listed in the National Shelter Survey (NSS) will provide a protection factor (PF) of at least 40, thus meeting the fallout protection requirement. Consequently, it seems that close-in shelter for the workers should be identified in NSS buildings which also are capable of providing protection from the direct effects of nuclear weapons. The following paragraphs describe these types of buildings in terms of their construction characteristics and ranks them according to their protective capability.

The Illinois Institute of Technology Research Institute (IITRI) estimated people survivability for a 25-building sample drawn from a national, statistically valid sample of 219 NSS buildings (Ref. 20). Percent survivors were calculated for free field overpressures ranging up to 20 psi. Additionally, a combined 50-building sample was statistically analyzed by considering the influence of all reasonable variations and

combinations of available building characteristics on people survivability. The results of this analysis were used to develop a ranking method for conventional buildings in terms of best available shelter spaces.

Table 20 contains a categorization of buildings included in the combined IITRI sample. Of the 50 buildings, 36 are of framed construction, 3 are load-bearing, and 11 are a combination of the two. Table 20 also lists the percent of total shelter spaces contained in each type of building as estimated by RTI (Ref. 21). It indicates that 73.1 percent of shelter spaces are in framed buildings (54.4 percent in framed buildings with arching walls and the remaining 18.7 percent in framed buildings with either curtain walls or reinforced concrete walls), 2.3 percent in combination framed and load-bearing-wall buildings, and 24.6 percent in load-bearing-wall buildings.

Table 21 displays the percent survivors at five different free field overpressures for each of the 50 buildings. These estimates are for people in the upper stories in two different positions, initially standing and initially prone. Table 22 lists these results for people in the initially standing position and Table 23 lists these results for people in the initially prone position. The following example illustrates how these tables were derived:

> For combination buildings with people initially standing, 7 of the 11 buildings afford greater than 90 percent survivability at 4 psi overpressure, therefore P (90 percent or more survivors, 4 psi) = 7/11 = .64.

These data were then used to derive survival probabilities by building type, i.e. framed, combination, and load-bearing.

IITRI further estimated survivability as a function of wall type and frame type in addition to building type. Table 24 presents average percent survivors according to building, wall and frame type, as derived from the information in Table 21. Table 25 presents average percent survivors in framed buildings according to wall type and frame type. A close examination of these tables shows that the average percent survivors is always greater for people in the initially prone position than for people initially standing. Figure 2 graphically illustrates the relationships between prone and standing personnel at 50 percent survivors overpressure.

Using the data from Table 24, it is possible to rank building categories relative to protection afforded people in the upper stories.

Table 20. Categorization of Buildings Included in the Combined IITRI Sample 1/

Building Type	Exterior Wall Type	Frame Type	Number in Sample	Percent of Total Spaces in U.S.
Framed	NLBW-A	Steel	11	
		R/C	12	54.4
		Steel - R/C	4	
	NLBW-NA	Steel	6	
		R/C	2	
				18.7
	R/C	R/C	1	
			36	73.1
Combination	LBW	Steel	5	
		R/C	6	
			11	2.3
Load-bearing	LBW	--	3	24.6
Total			50	100.0

1/ Ref. 20.

Table 21. Percent Survivors at Indicated Overpressures 1/

Building Type	Wall Type	Frame Type	Building Number	Percent Survivors by Overpressure (psi)									
				Standing					Prone				
				4	8	12	16	20	4	8	12	16	20
Framed	NLBW-A	Steel	13	98	32	2	1	0	99	77	64	30	0
			51	98	45	0	0	0	100	98	10	2	0
			76	99	48	8	4	2	100	99	78	65	5
			161	98	15	1	0	0	100	75	8	0	0
			223	98	67	40	30	10	100	99	90	84	30
			44	96	31	0	0	0	100	96	10	0	0
			139	96	56	27	12	1	95	84	81	60	4
			152	91	55	28	18	4	100	96	93	74	9
			160	98	73	48	41	40	100	100	91	76	67
			168	98	20	0	0	0	100	28	12	0	0
			179	99	14	0	0	0	100	36	15	0	0
		R/C	62	92	20	2	0	0	100	80	16	0	0
			84	95	13	2	0	0	99	75	11	0	0
			130	99	20	2	0	0	100	80	35	13	0
			136	98	20	2	0	0	100	85	20	7	0
			146	93	8	5	0	0	98	50	0	0	0
			204	99	90	20	9	0	100	100	60	9	0
			7	98	55	9	0	0	100	100	100	14	0
			20	58	18	0	0	0	100	27	11	0	0
			29	88	10	0	0	0	86	13	6	0	0
			56	33	4	0	0	0	85	28	5	0	0
			212	96	14	0	0	0	100	45	14	0	0
			239	98	79	0	0	0	100	100	4	0	0
		Steel-R/C	35	98	45	0	0	0	100	87	5	0	0
			93	99	30	0	0	0	100	68	60	0	0
			140	95	30	2	1	0	100	88	45	15	0
			89	98	65	0	0	0	100	100	10	0	0
	NLBW-NA	Steel	55	50	3	0	0	0	100	67	4	1	0
			63	95	15	2	0	0	100	90	20	6	0
			228	60	18	0	0	0	100	75	42	1	0
			36	56	4	0	0	0	96	56	21	0	0
			37	40	1	0	0	0	100	70	3	1	0
			114	91	26	0	0	0	89	45	23	0	0
		R/C	81	98	45	3	0	0	100	100	85	0	0
			129	47	18	0	0	0	91	37	12	0	0
	R/C	R/C	198	95	48	3	2	0	98	87	76	20	0
Combination	LBW	Steel	132	96	4	0	0	0	99	40	3	0	0
			6	97	50	8	3	0	100	98	61	26	0
			119	10	2	0	0	0	12	2	1	0	0
			147	62	48	39	35	32	79	65	56	49	40
			202	100	35	22	23	24	100	48	47	22	23
		R/C	143	97	20	0	0	0	100	80	18	0	0
			171	96	20	1	0	0	100	75	8	0	0
			195	98	15	2	0	0	100	65	10	0	0
			207	97	40	1	0	0	100	95	43	3	0
			250N	60	16	3	3	0	99	50	28	3	0
			177	17	6	0	0	0	20	10	4	0	0
LBW	LBW		33	97	40	5	1	0	100	95	41	6	1
			66	97	10	0	0	0	100	19	0	0	0
			138	0	0	0	0	0	0	0	0	0	0

1/ Ref. 20.

Table 22. Survival Probabilities Initially Standing People in Three Building Types 1/

Building Type	Percent of U.S. Spaces	Overpressure (psi)	Percent Survivors (Lower Limit) 1	10	20	30	40	50	60	70	80	90	100
Frame	73.1	4	1.00	1.00	1.00	1.00	0.97	0.91	0.80	0.80	0.80	0.77	0.00
Combination	2.3		1.00	1.00	0.82	0.82	0.82	0.82	0.82	0.64	0.64	0.64	0.09
LBW	24.6		0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.00
Frame	73.1	8	1.00	0.86	0.61	0.47	0.36	0.22	0.14	0.08	0.08	0.03	0.00
Combination	2.3		1.00	0.72	0.54	0.36	0.27	0.09	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.67	0.67	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Frame	73.1	12	0.84	0.14	0.14	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Combination	2.3		0.63	0.18	0.18	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frame	73.1	16	0.22	0.11	0.05	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Combination	2.3		0.36	0.18	0.18	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frame	73.1	20	0.14	0.05	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Combination	2.3		0.18	0.18	0.18	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1/ Ref. 20.

Table 23. Survival Probabilities Initially Prone People in Three Building Types 1/

Building Type	Percent of U.S. Spaces	Overpressure (psi)	Percent Survivors (Lower Limit)										
			1	10	20	30	40	50	60	70	80	90	100
Frame	73.1	4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.72
Combination	2.3		1.00	1.00	0.91	0.31	0.81	0.81	0.81	0.81	0.73	0.73	0.54
LBW	24.6		0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Frame	73.1	8	1.00	1.00	1.00	0.97	0.94	0.84	0.75	0.69	0.55	0.36	0.19
Combination	2.3		1.00	0.91	0.81	0.81	0.81	0.63	0.54	0.36	0.27	0.18	0.00
LBW	24.6		0.67	0.67	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.00
Frame	73.1	12	0.97	0.87	0.70	0.45	0.42	0.36	0.36	0.25	0.20	0.14	0.05
Combination	2.3		1.00	0.63	0.45	0.36	0.36	0.18	0.09	0.00	0.00	0.00	0.00
LBW	24.6		0.33	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Frame	73.1	16	0.47	0.27	0.16	0.16	0.14	0.14	0.14	0.08	0.05	0.00	0.00
Combination	2.3		0.45	0.27	0.27	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frame	73.1	20	0.14	0.08	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.00	0.00
Combination	2.3		0.18	0.18	0.18	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00
LBW	24.6		0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1/ Ref. 20.

Table 24. Average Percent Survivors According to Building, Wall and Frame Type 1/

Building Type	Wall Type	Frame Type	Sample Size	Standing Overpressure (psi)					Prone Overpressure (psi)				
				4	8	12	16	20	4	8	12	16	20
	NLBW-A	Steel	11	97.2	41.5	14.0	9.6	5.2	99.5	80.7	50.2	35.5	10.5
		R/C	12	87.2	29.3	3.5	0.8	0.0	97.3	65.3	23.5	3.6	0.0
		Steel, R/C	4	97.5	42.5	0.5	0.3	0.0	100.0	85.8	30.0	3.8	0.0
Framed	NLBW-NA	Steel	6	65.3	11.2	0.3	0.0	0.0	97.5	67.2	18.8	1.5	0.0
		R/C	2	72.5	31.5	1.5	0.0	0.0	95.5	68.5	48.5	0.0	0.0
	R/C	R/C	1	95.0	48.0	3.0	2.0	0.0	98.0	87.0	76.0	20.0	0.0
Combination	LBW	Steel	5	73.0	27.8	13.8	12.2	11.2	78.0	50.6	33.6	19.4	12.6
		R/C	6	77.5	19.5	1.2	0.5	0.0	86.5	62.5	18.5	1.0	0.0
Load-bearing	LBW	--	3	64.7	16.7	1.7	0.3	0.0	66.7	38.0	13.7	2.0	0.3

1/ Ref. 20.

Table 25. Average Percent Survivors in Framed Buildings According to Wall Type and Frame Type 1/

Wall Type	Frame Type	Sample Type	Standing Overpressure (psi) 4	8	12	16	20	Prone Overpressure (psi) 4	8	12	16	20
NLBW-A		27	92.8	36.2	7.3	4.3	2.1	98.6	74.6	35.3	16.6	4.3
NLBW-NA		8	67.1	16.2	0.6	0.0	0.0	97.0	67.5	26.2	1.1	0.0
R/C		1	95.0	48.0	3.0	2.0	0.0	98.0	87.0	76.0	20.0	0.0
	Steel	17	85.9	30.8	9.2	6.2	3.4	98.8	75.9	39.1	23.5	6.8
	R/C	15	85.8	30.8	3.2	0.7	0.0	97.1	67.1	30.3	4.2	0.0
	Steel, R/C	4	97.5	42.5	0.5	0.3	0.0	100.0	85.8	30.0	3.8	0.0

1/ Ref. 20.

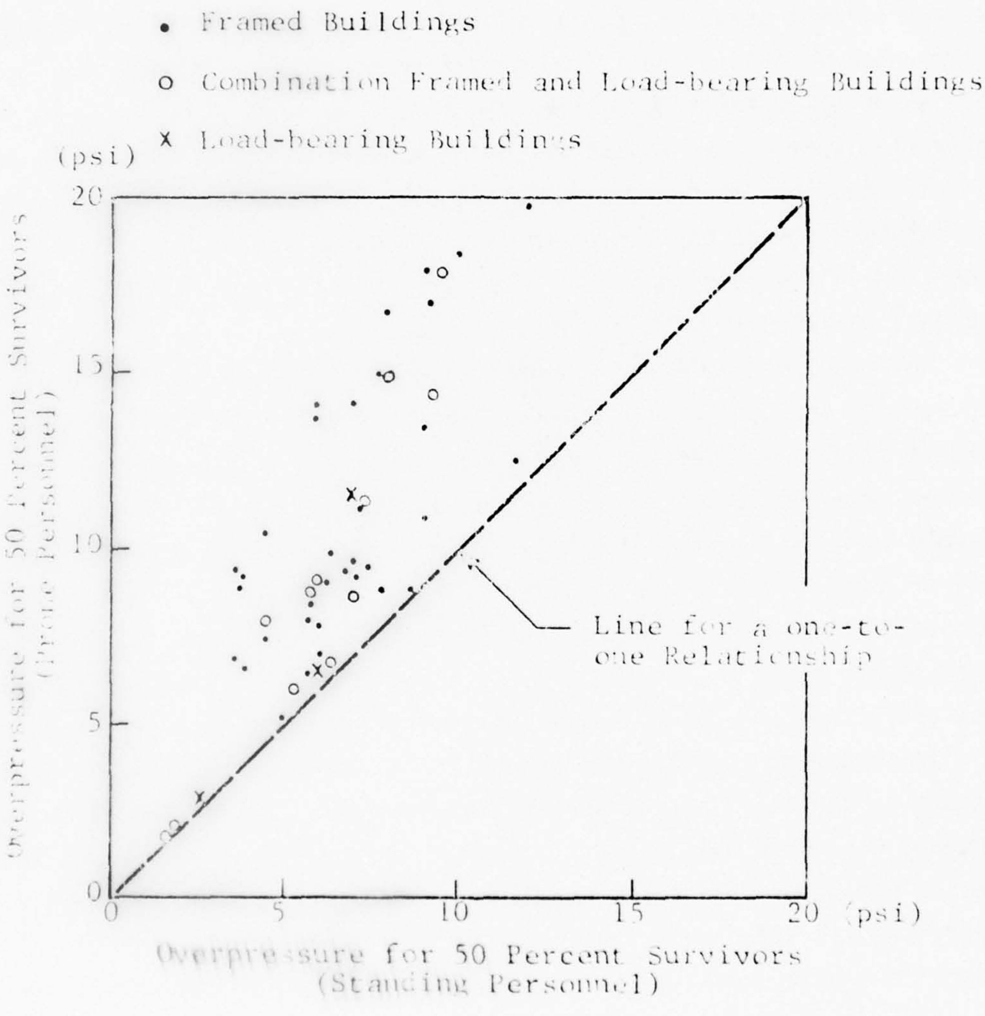


Figure 2. Relationship Between Prone and Standing Personnel at 50 Percent Survivors Overpressure. 1/

1/ Ref. 20.

IITRI performed a statistical analysis to achieve this. Briefly, this analysis went as follows: for each position (initially standing or prone) and overpressure, the buildings were ranked according to the average percent survivors. Each pair of buildings was statistically analyzed to determine if the means were significantly different. Pairs of buildings whose average percent survivors were not significantly different were placed in the same homogeneous group. Overlapping of homogeneous groups could occur when the average percent survivors for a building category was not significantly different from that of buildings in different groups. Homogeneous groups were arranged in descending order by average percent survivors. Building categories were ranked in the following manner: building categories occurring only in the first group ranked the highest, followed by those occurring in the intersection of the first and second groups, followed by those occurring in the intersection of the first three groups, etc. Table 26 presents the results of the statistical analysis.

Before drawing any conclusions concerning the best available close-in aboveground shelter for key workers, some comments from IITRI about the results should be noted. In analyzing the survivability of people in upper stories, average values for any given building were used. People were assumed to be uniformly distributed throughout the building and only one mode of evasive action was considered, that of assuming a prone position as opposed to remaining standing. Therefore, the results may be conservative, since people could be located only in areas of the building affording the most protection and could assume positions other than prone or standing. It is also important to note that the building sample is not well balanced with respect to the building characteristics analyzed. For instance, the sample contains 36 framed buildings, 11 combination buildings, and only 3 load-bearing buildings. Furthermore, 27 buildings with arching walls, 8 with nonarching walls and only 1 with reinforced concrete walls were included. From this sample, nothing conclusive can be said about the protective capabilities of framed buildings with reinforced concrete walls.

Close-in shelter should be capable of offering protection from blast overpressures in the 16 psi range. Table 26 shows that, at this overpressure, framed buildings with nonload-bearing walls with arching support conditions and steel frames, combination buildings with load-bearing walls and steel frames, and frame buildings with reinforced concrete walls and frames afford the best protection. However, even when it is assumed that the shelter occupants are initially in prone positions, the average percent

Table 26. Results from Statistical Ranking From 1 (Best) to 9 (Worst) with Probability Level of 0.20 1/

Building Category	Standing (psi)					Prone (psi)				
	4	8	12	16	20	4	8	12	16	20
Frame - NLBW-A - Steel	1-2	1-3	1	1-2	1-2	2-4	1-2	1-2	1-3	1-2
Frame - NLBW-A - R/C	4	4-6	3	4-9	5-9	5-9	5-9	6-9	4-5	3-9
Frame - NLBW-A - Steel, R/C	1-2	1-3	8	4-9	5-9	1	1-3	3-5	4-5	3-9
Frame - NLBW-NA - Steel	8-9	9	9	4-9	5-9	2-4	5-9	6-9	6-7	3-9
Frame - NLBW-NA - R/C	5-7	4-6	5-7	4-9	3-4	5-9	4	3-5	8-9	3-9
Frame - R/C - R/C	3	1-3	4	3	3-4	2-4	1-3	1-2	1-3	3-9
Combination - LBW - Steel	5-7	4-6	2	1-2	1-2	5-9	5-9	3-3	1-3	1-2
Combination - LBW - R/C	5-7	7-8	5-7	4-9	5-9	5-9	5-9	6-9	8-9	3-9
LBW - LBW	8-9	7-8	5-7	4-9	5-9	5-9	5-9	6-9	6-7	3-9

1/ Ref. 20.

survivors in these three building types ranges from 35.5 percent to 19.4 percent. This is clearly not acceptable; alternatives must be sought.

One possible alternative is to evacuate key workers to distances where the anticipated blast overpressures are lower, so that the workers can be sheltered in aboveground stories. For example, at 8 psi overpressure, framed buildings with nonload-bearing walls with arching support conditions and steel frames, framed buildings with nonload-bearing walls with arching support conditions and steel and reinforced concrete frames, and framed buildings with reinforced concrete walls and frames offer the best protection. With the shelter occupants in initially prone positions, the average percent survivors for these three building types ranges from 87.0 percent to 80.7 percent. These are much greater percent survivor figures than at 16 psi. However, if essential production and service functions are to be maintained in all high risk areas, other alternatives must be identified.

Table 27 displays the distribution of fallout shelter spaces by shelter story location as estimated by RTI (Ref. 21). It can be seen that 33.4 percent of the spaces in the sample are in basements. Basements should afford better protection from overpressures than do aboveground stories, though significant numbers of basement shelter spaces are not available in all areas of the country. IITRI's sample of 50 buildings included 36 buildings with basements. Table 28 presents these buildings, categorized by the type of overhead (first) floor system. Table 29 displays the fallout shelter spaces in basements by type of first story floor system as estimated by RTI (Ref. 21). Table 30 is a summary of Tables 28 and 29. It contains a breakdown of basement spaces; shows the number of spaces, percent of total spaces, and percent of basement spaces for each type of overhead floor system.

IITRI estimated the percent survivors for each basement in the sample at eight different overpressures. Table 31 displays this information. The information contained in Table 31 was used to estimate survival probabilities in the same manner that survival probabilities were estimated for people in upper stories. Table 32 displays the results of these calculations for the four lowest overpressures. At overpressures greater than 20 psi, the survival probabilities are very low. The information in Table 31 was further used to derive the entries in Table 33. Table 33 lists the

Table 27. Estimated Fallout Shelter Spaces by Shelter Story Location 1/

Story	Est. NSS Spaces (000)	Est. Percent Spaces
4 and 5 sub-basements	40	.0
2 and 3 sub-basements	743	.4
First sub-basement	2946	1.7
Basement	57,843	33.4
Crawl space	193	.1
First story	30,797	17.8
2 and 3 story	32,103	18.5
4 and 5 story	14,966	8.6
6 to 10 story	16,820	9.7
11 to 20 story	10,861	6.3
21 to 50 story	5,775	3.3
51 and over	277	.2
Total	173,369	100.0

*These estimates are based on the 219 sample buildings surveyed within the Continental United States. The total of 173,369,000 spaces represents 83.3 percent of the 208,043,000 spaces in the NSS inventory as of January 1972.

1/ Ref. 21.

Table 28. Basement Overhead (First) Floor Systems in Sample 1/

Type of Floor System		Number in Sample
1. Concrete slab-steel beam		9
2. Flat slab		6
3. Flat plate		2
4. Concrete slab-concrete beam		3
5. Concrete joist-concrete beam		1
6. Concrete joist-steel beam		3
7. Other:		
Concrete slab-concrete joist	7	
Concrete slab-steel joist	3	12
Concrete slab-steel/concrete beam	1	
Hollow concrete slab	1	
Total Sample		36

1/ Ref. 20.

Table 29. Estimated Fallout Shelter Spaces in Basements by Type of First Story Floor System* 1/

Floor Deck (Code - Description)	Estimated Shelter Spaces [Number (000)/Percent] By First Story Floor System								
	Floor Frame (Code and Description)								
		F11	F12	F13	F14	F15	F16	F17	
	Not Reported	Timber Beams	Steel Beams	Open Web Joists	Conc. Beams Cast-in-place	Conc. Beams Precast	Conc. Beams Precast and Prestressed	No Beams	Total
Not Reported	389 .7	0 0.0	196 .3	792 1.4	0 0.0	0 0.0	0 0.0	0 0.0	1377 2.4
F21-Wood Plank	0 0.0	138 .2	2038 3.5	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	2177 3.8
F22-Plywood	0 0.0	792 1.4	0 0.0	0 0.0	0 0.0	792 1.4	0 0.0	0 0.0	1583 2.7
F23-Concrete-Ordinary Slab	100 .2	0 0.0	13943 24.1	4940 8.5	14400 24.9	0 0.0	0 0.0	4761 8.2	38144 65.9
F24-Concrete (Lift Slab)	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	669 1.2	669 1.2
F25-Concrete-One-way Ribbed Joists	0 0.0	0 0.0	1480 2.6	0 0.0	7719 13.3	0 0.0	0 0.0	706 1.2	9905 17.1
F26-Concrete-Two-way Ribbed Joists	0 0.0	0 0.0	0 0.0	0 0.0	281 .5	0 0.0	0 0.0	35 .1	316 .5
F27-Concrete-Precast Panels	0 0.0	0 0.0	0 0.0	0 0.0	30 .1	0 0.0	792 1.4	476 .8	1298 2.2
F28-Cellular Steel and Concrete	0 0.0	0 0.0	45 .1	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	45 .1
F29-Composite Steel and Concrete	0 0.0	0 0.0	2325 4.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	2325 4.0
Total	489 .8	930 1.6	20026 34.6	5732 9.9	22429 38.8	792 1.4	792 1.4	6648 11.5	57843 100.0

* These estimates are based on the 219 sample buildings surveyed within the Continental United States. The total of 57,843,000 basement shelter spaces represents 27.8 percent of the 208,043,000 spaces in the NFSS inventory as of January 1972.

1/ Ref. 21.

Table 30. Breakdown of Basement Spaces*

Type of Overhead Floor System	Total Spaces in U.S.(000)	Percent of Total U.S. Spaces	Percent of Total Basement Spaces
Concrete slab steel beam	13,940	8.0	24.1
Flat slab	2,603	1.5	4.5
Flat plate	2,834	1.6	4.9
Concrete slab - concrete beam	14,403	8.3	24.9
Concrete joist - concrete beam	7,693	4.4	13.3
Concrete joist - steel beam	1,504	0.9	2.6
Other	14,866	8.7	25.7
Total Basement Spaces	57,843	33.4	100.0

* These estimates are based on the 219 sample buildings surveyed within the Continental United States. The total of 57,843,000 basement spaces represents 33.4 percent of the 173,369,000 spaces in the RTI sample (Ref. 21).

Table 31. Percent Survivors for Indicated Overpressures 1/

Basement Overhead (First) Floor System	Building Number	Free-Field Overpressure (psi)							
		5	10	15	20	25	30	35	40
Concrete slab-steel beam	35	100	40	0	0	0	0	0	0
	51	100	79	61	10	0	0	0	0
	55	100	97	33	0	0	0	0	0
	161	100	87	59	0	0	0	0	0
	36	83	38	0	0	0	0	0	0
	37	100	100	100	93	73	52	29	4
	130	37	0	0	0	0	0	0	0
	147	50	0	0	0	0	0	0	0
	160	100	100	71	20	0	0	0	0
Flat slab	84	100	23	0	0	0	0	0	0
	93	100	0	0	0	0	0	0	0
	204	100	95	71	40	0	0	0	0
	6	100	0	0	0	0	0	0	0
	66	100	46	36	26	15	5	0	0
	212	13	0	0	0	0	0	0	0
Flat plate	29	57	0	0	0	0	0	0	0
	129	0	0	0	0	0	0	0	0
Concrete slab-concrete beam	146	95	48	8	0	0	0	0	0
	223	55	0	0	0	0	0	0	0
	20	100	83	11	0	0	0	0	0
Concrete joist-concrete beam	114	77	0	0	0	0	0	0	0
Concrete joist-steel beam	152	50	36	22	8	0	0	0	0
	13	100	41	7	0	0	0	0	0
	179	100	63	0	0	0	0	0	0
<u>Other</u>:									
Concrete slab-concrete joist	76	98	10	0	0	0	0	0	0
	81	65	0	0	0	0	0	0	0
	44	35	0	0	0	0	0	0	0
	136	0	0	0	0	0	0	0	0
	198	73	0	0	0	0	0	0	0
	138	90	30	0	0	0	0	0	0
	177	100	33	0	0	0	0	0	0
Concrete slab-steel joist	63	90	19	0	0	0	0	0	0
	228	90	0	0	0	0	0	0	0
	168	100	59	0	0	0	0	0	0
Concrete slab-steel concrete beam	56	100	0	0	0	0	0	0	0
Hollow concrete slab	239	100	63	0	0	0	0	0	0

1/ Ref. 20.

Table 32. Percent of Survivors Probability According to Floor System Type 1/

Basement Overhead (First) Floor System	Overpressure (psi)	Percent Survivors (Lower Limit) 1	10	20	30	40	50	60	70	80	90	100
Concrete slab-steel beam	5	1.00	1.00	1.00	1.00	0.89	0.89	0.78	0.78	0.78	0.67	0.67
Flat slab		1.00	1.00	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Flat plate		0.50	0.50	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00
Concrete slab-concrete beam		1.00	1.00	1.00	1.00	1.00	1.00	0.67	0.67	0.67	0.67	0.33
Concrete joist-concrete beam		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
Concrete joist-steel beam		1.00	1.00	1.00	1.00	1.00	1.00	0.67	0.67	0.67	0.67	0.67
Other		0.92	0.92	0.92	0.92	0.83	0.83	0.83	0.67	0.58	0.58	0.33
Concrete slab-steel beam	10	0.78	0.78	0.78	0.78	0.67	0.55	0.55	0.55	0.44	0.33	0.22
Flat slab		0.50	0.50	0.50	0.33	0.33	0.17	0.17	0.17	0.17	0.17	0.00
Flat plate		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete slab-concrete beam		0.67	0.67	0.67	0.67	0.67	0.33	0.33	0.33	0.33	0.00	0.00
Concrete joist-concrete beam		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete joist-steel beam		1.00	1.00	1.00	1.00	0.67	0.33	0.33	0.00	0.00	0.00	0.00
Other		0.50	0.50	0.33	0.33	0.17	0.17	0.08	0.00	0.00	0.00	0.00
Concrete slab-steel beam	15	0.56	0.56	0.56	0.56	0.44	0.44	0.33	0.22	0.11	0.11	0.11
Flat slab		0.33	0.33	0.33	0.33	0.17	0.17	0.17	0.17	0.00	0.00	0.00
Flat plate		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete slab-concrete beam		0.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete joist-concrete beam		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete joist-steel beam		0.67	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete slab-steel beam	20	0.22	0.22	0.22	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.00
Flat slab		0.33	0.33	0.33	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Flat plate		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete slab-concrete beam		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete joist-concrete beam		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concrete joist-steel beam		0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1/ Ref. 20.

Table 33. Average Percent Survivors (Basement Spaces) 1/

Floor System	Free Field Overpressure (psi) 5	10	15	20	25	30	35	40
Concrete slab-steel beam	85.6	60.1	36.0	13.7	8.1	5.8	3.2	0.4
Flat slab	85.5	27.3	17.8	11.0	2.5	0.8	0.0	0.0
Flat plate	28.5	00.0	00.0	00.0	0.0	0.0	0.0	0.0
Concrete slab-concrete beam	83.3	43.7	6.3	00.0	0.0	0.0	0.0	0.0
Concrete joist-concrete beam	77.0	0.0	0.0	00.0	0.0	0.0	0.0	0.0
Concrete joist-steel beam	83.3	46.7	9.7	2.7	0.0	0.0	0.0	0.0
Other	78.4	17.8	0.0	0.0	0.0	0.0	0.0	0.0

Table 34. Ranking of Basement Spaces 1/

Basement Overhead (First) Floor System	Free Field Overpressure (psi) 5	10	15	20	25	30	35	40
Concrete slab-steel beam	1	1	1	1	1	1	1	1
Flat slab	2	4	2	2	2	2	2-7	2-7
Flat plate	6-7	6-7	5-7	4-7	5-7	3-7	2-7	2-7
Concrete slab-concrete beam	3	3	4	4-7	5-7	3-7	2-7	2-7
Concrete joist-concrete beam	5	6-7	5-7	4-7	5-7	3-7	2-7	2-7
Concrete joist-steel beam	3	2	3	3	5-7	3-7	2-7	2-7
Other	4	5	5-7	4-7	5-7	3-7	2-7	2-7

1/ Ref. 20.

average percent survivors as a function of overhead floor system and free field overpressure.

IITRI did not perform a statistical ranking of basement spaces in the same manner as it did for overhead spaces because of the smaller sample of basements involved. Therefore, a simple ranking system was used. Table 34 displays the ranking of basement spaces at eight different overpressures on the basis of average percent survivors (as listed in Table 30). The ranking is from 1 (best) to 7 (worst).

At the 15 psi free field overpressure level from which protection is needed in close-in shelters, the concrete slab-steel beam, flat slab, and concrete joist-steel beam floor systems afford the highest probabilities of survival. However, even in basements with these overhead floor systems, average percent survivors range from 36.0 percent down to 9.7 percent. This is not significantly different from the survivability of people in the three best types of aboveground buildings. Furthermore, these probabilities of survival are not acceptable. Though IITRI (Ref. 20) notes that, "since debris is the primary casualty producer in basements, while debris, thermal radiation, prompt nuclear radiation and dynamic pressure are prevalent in upper stories, then it is reasonable to assume that survivors in basements will have fewer injured personnel than in upper stories" it is clear that close-in sheltering of key workers in existing basements with no upgrading is not a viable alternative.

In summary, the only type of existing facility capable of sheltering key workers from free field overpressures up to 15 psi are special facilities (i.e. mines, caves, and tunnels). Since this type of shelter is not available near most high-risk areas, alternatives must be identified. One alternative is to evacuate the key workers to areas subject to lower overpressures. Some types of existing buildings afford adequate protection from free field overpressures in the 5 psi to 8 psi range. This is not a desirable alternative, however, because in some high-risk areas, it will not be possible to maintain essential service and production functions. The only other viable alternative seems to be expedient upgrading of existing buildings so that they will withstand free field overpressures in the 15 psi to 16 psi range.

Stanford Research Institute (SRI) has performed research into methods of expediently upgrading basements for combined nuclear weapons effects (Ref. 19). SRI considered the following protective measures:

- Prevention of air blast entry (closed shelter mode)
- Air blast loading reduction on basement exterior surfaces
- Air blast structural strengthening
- Provision of last resort protection from debris and failed floors and walls
- Provision of additional radiation protection

This study is a good start towards identifying means of providing close-in shelter for key workers, but, as SRI (Ref. 1) notes, "only general methodology and materials were considered without attention to the degree of blast protection provided. It remains necessary to provide degree of protection guidance as a function of materials and methods."

VI. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Because of the limited scope of the work under this project, it was not possible to conduct field surveys to obtain data relating to the definition of facility characteristics. Instead, all data was extracted from existing publications and survey data. Therefore, in using the information compiled herein that pertains to facility characteristics, it is important to recognize the limitations of the data.

Lighting and ventilation requirements of four different building codes are presented to demonstrate consistencies among the codes, not for the purpose of estimating building characteristics in different geographical regions of the country. The information presented should be representative of the building code requirements for lighting and ventilation over the entire country. Of course, a particular building should not be expected to conform exactly to the requirements presented herein. These are only minimum requirements and may even be different from those that were in effect at the time and place that a particular building was constructed.

CRP Host Area Facility Listing data from four counties in the United States are represented in the summary of large shelter facility characteristics. These data pertain to the frequency of occurrence of buildings in the different use classes, the nature of the water supply, the number of permanent commodes, and the presence of emergency generators. Because this information was obtained from actual host area buildings, it may be more representative of the characteristics of rural buildings than are the building code requirements for lighting and ventilation. However, the summary of large shelter facility characteristics is derived from a very small sample of the total number of counties in the United States; and therefore, it may be biased.

In describing the options for providing services, it was found that existing survey data are inadequate for developing detailed alternatives for the provision of lighting, ventilation, water supply, excreta disposal, and solid waste disposal systems. Additional information needed by local planners to develop detailed plans for a specific building includes the following items:

- Specifications for existing electrical power distribution systems
- Specifications for existing engine-generators, including the type of transfer swtich
- Specifications for existing mechanical ventilation systems, including the amount of air normally recirculated
- Method of water delivery through the existing water supply system (pumped from reservoir, gravity feed from reservoir, etc.)
- Well capacity, pump capacity, and the water line size where wells exist
- Number of watering points available in the building
- Type of sewage disposal system (septic tank, tertiary treatment, etc.)
- Capacity of the sewage disposal system
- Number and capacity of existing incinerators

A problem of greater importance to the development of shelter service plans, is the absence of reliable, up-to-date guidelines to use as the basis for determining system capacities and material requirements. For instance, further research is needed into the following problems associated with the design and implementation of ventilation systems:

- The deployment procedure for Kearny pumps used for air distribution needs modification to reflect the knowledge gained from the most recent research.
- Upgrading techniques need to be developed that will not interfere with the ventilation systems in shelters requiring blast and/or fallout upgrading.
- Problems associated with shelter ventilation in very cold weather should be investigated and guidance should be developed for shelter occupants in the event of such an occurence.

There seems to be an even more critical need for further research in the areas of water supply, human excreta disposal, and solid waste disposal. In each of these cases the total shelter requirement for these services is obtained by multiplying the shelter capacity (determined by the amount of usable floor area) by the requirement per person. This method is only as

valid as the figures for basic per person requirements since the civil defense planner must use such basic per person values in estimating the amount by which each of these services must be upgraded in a shelter facility.

In the present study, as well as in previous work on the subject, a recurring problem has been determining realistic values for these services to meet basic human needs. This problem is illustrated in the following matrix. X's represent parameters for which realistic values are needed.

	Men	Women	Children	Weighted Average	Allowance for Loss	Extra Capacity
Drinking water	X	X	X	X	X	
Water for other uses	X	X	X	X	X	
Human waste production	X	X	X	X		X
Toilet facilities needed	X	X	X	X		X
Solid waste production				X		X
Food service facilities				X		X
Ventilation				X	X	X
Space	X	X	X	X		X

Currently assumed basic values may be unrealistic to the extent that they do not reflect the actual quantities of the various services required to fulfill the basic human needs of a large, stressed, sheltered population.

An example of the problem was RTI's attempt to identify a value for per person excreta production (and therefore disposal requirements). An extensive literature search revealed six different sources of this value, none of which are in agreement. In addition, the DCPA Attack Environment Manual (Ref. 14) states that when "water intake is restricted or negligible,

the bodies of healthy people compensate first by reducing the amount of urine excretion by half," which indicates that none of the figures found in the literature may be realistic in determining critical shelter features. A similar dilemma was found to exist for other basic human needs (e.g. water, solid waste, toilets) after reviewing various technical publications from the World Health Organization, Public Health Service, and DCPA, and after talking with disaster-oriented Red Cross personnel. A further complication is that planning assumptions may also affect design values for basic human needs. Some of these planning factors include:

- Period of shelter use
- Mix of population
- Type of food service
- Availability of power
- Availability of water supply (pressure versus no pressure)

The final product of further research into this problem should be per person needs as a function of varying planning assumptions, as well as other factors such as those listed above.

Finally, as was stated in the conclusion of the section entitled "Close-in Shelter for Key Workers," SRI has performed research into methods of expediently upgrading basements for combined nuclear weapons effects. SRI notes that, "only general methodology and materials were considered without attention to the degree of blast protection provided. It remains necessary to provide degree of protection guidance as a function of materials and methods" (Ref. 19). When the materials and methods have been identified that will provide the desired degree of protection (15 to 16 psi overpressures), it will then be necessary to identify viable alternatives for providing services in these facilities. For example, the closed shelter mode presents different problems from those considered herein, particularly in the provision of ventilation.

This is not a definitive study on the provision of crisis implemented lighting, ventilation, water supply, sewage disposal, and solid wase disposal systems in large shelter facilities. However, it is hoped that the data and concepts collected herein serve to identify some of the problems and will provide guidance for future studies in these areas.

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Appendix A

MAJOR VEHICULAR TUNNELS IN THE UNITED STATES

Appendix A

MAJOR VEHICULAR TUNNELS IN THE UNITED STATES

This Appendix contains a listing of the major vehicular tunnels in the United States. The listing is divided into two parts, subaqueous tunnels and land tunnels. For each tunnel, the first seven columns of information (from State to Traffic Lanes per Bore) were supplied by the Federal Highway Administration, U.S. Department of Transportation. The last four columns of information (from Length Available for Shelter Use to Number of Shelter Spaces at 10 ft.^{2} per Person) were calculated based on the followinng assumptions:

- A PF of 40 is reached 50 feet inside the mouth of a tunnel.
- Traffic lanes built during or after 1956 are 12 feet wide; traffic lanes built before 1956 are 10 feet wide.
- Service ways, 4 feet wide, are located on both sides of the tunnels.

Part I: SUBAQUEOUS TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100[1] per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
Alabama	Bankhead Tunnel	Mobile River in Mobile (Toll facility)	3,109 ft. (0.589 mi.)	1941	1	2	3,009	28	84,252	8,425
California	Posey Tube	Oakland Inner Harbor between Oakland and Alameda on State Route 226	3,545 ft. (0.671 mi.)	1928	1	2	3,445	28	96,460	9,646
California	Webster Street Tube	Companion tunnel to Posey Tube	3,350 ft. (0.634 mi.)	1964	1	2	3,250	32	104,000	10,400
Florida	New River Tunnel	New River in Fort Lauderdale on U.S. Route 1	864 ft. (0.164 mi.)	1960	2	2	1,528	32	48,896	4,889
Louisiana	Belle Chase Tunnel	Intracoastal Waterway in Algeria on State Route 31	800 ft. (0.152 mi.)	1955	1	2	700	28	19,600	1,960
Louisiana	Harvey Tunnel	Intracoastal Waterway in Harvey on U.S. Route 90	1,080 ft. (0.205 mi.)	1957	2	2	1,960	32	62,720	6,272
Louisiana	Houma Tunnel	Intracoastal Waterway in Houma on State Route 3040	960 ft. (0.182 mi.)	1961	1	2	860	32	27,520	2,752
Maryland	Baltimore Harbor Tunnel	Patapsco River in Baltimore (Toll facility)	7,650 ft. (1.449 mi.)	1957	2	2	1,510	32	48,320	4,832
Massachusetts	Sumner Tunnel	Boston Inner Harbor between Boston and East Boston (Toll Facility)	5,635 ft. (1.067 mi.)	1934	1	2	5,535	28	154,980	15,498
Massachusetts	Lt. William F. Callahan, Jr. Tunnel	Companion tunnel to Sumner Tunnel (Toll facility)	5,046 ft. (0.956 mi.)	1962	1	2	4,946	32	158,272	15,827
Michigan	Detroit-Windsor Tunnel	Detroit River between Detroit, Mich., and Windsor, Ontario, Canada (Toll facility)	5,135 ft. (0.973 mi.)	1930	1	2	5,035	28	140,980	14,098

Part I: (cont'd). SUBAQUEOUS TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100 per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
New York	Holland Tunnel	Hudson River between Jersey City, N.J., and New York, N.Y. (Toll facility)	8,464 ft. (1.603 mi.)	1927	2	2	16,728	28	468,384	46,838
New York	Lincoln Tunnel	Hudson River between Weehawken, N.J., and New York, N.Y. (Toll facility)								
		North Tunnel	7,482 ft. (1.417 mi.)	1945	1	2	7,382	28	206,696	20,669
		Center Tunnel	8,216 ft. (1.556 mi.)	1937	1	2	8,116	28	227,248	22,724
		South Tunnel	8,006 ft. (1.516 mi.)	1957	1	2	7,906	32	252,992	25,299
New York	Queens-Midtown Tunnel	East River between the Borough of Manhattan and the Borough of Queens in New York (Toll facility)	6,343 ft. (1.201 mi.)	1940	2	2	12,486	28	349,608	34,960
New York	Brooklyn Battery Tunnel	East River between the Borough of Manhattan and the Borough of Brooklyn in New York (Toll facility)	9,117 ft. (1.727 mi.)	1950	2	2	18,034	28	504,952	50,495
Texas	Washburn Tunnel	Houston Ship Channel between Pasadena and Galena Park	2,936 ft. (0.556 mi.)	1950	1	2	2,836	28	79,408	7,940
Texas	Baytown Tunnel	Houston Ship Channel between Baytown and LaPorte on State Route 146	3,009 ft. (0.570 mi.)	1953	1	2	2,909	28	81,452	8,145
Virginia	Elizabeth River Tunnel No. 1 (Downtown Tunnel)	Southern Branch of the Elizabeth River between Berkley and Portsmouth (Toll facility)	3,350 ft. (0.634 mi.)	1952	1	2	3,250	28	91,000	9,100
Virginia	Elizabeth River Tunnel No. 2 (Midtown Tunnel)	Elizabeth River between Portsmouth and Norfolk (Toll facility)	4,194 ft. (0.794 mi.)	1962	1	2	4,094	32	131,008	13,100

Part I: (cont'd) SUBAQUEOUS TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length 100' per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
Virginia	Hampton Roads Tunnel	Hampton Roads at Chesapeake Bay between Hampton and Norfolk (Toll Facility)	7,479 ft. (1.416 mi.)	1957	1	2	7,379	32	236,128	23,612
Virginia	Chesapeake Bay Bridge Tunnel	Lower Chesapeake Bay between Cape Henry and Cape Charles (Toll Facility)								
	(a) Baltimore Channel Tunnel	Tunnel under northerly channel	5,450 ft. (1.032 mi.)	1964	1	2	5,350	32	171,200	17,120
	(b) Thimble Shoal Channel Tunnel	Tunnel under southerly channel	5,738 ft. (1.087 mi.)	1964	1	2	5,638	32	180,416	18,041

Part II: LAND TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length 100' per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
Arizona	Queen Creek Tunnel	U.S. 60, 70 between Superior and Miami	1,200 ft. (.227 mi.)	1953	1	3	1,100	38	41,800	4,180
Arizona	Mule Pass Tunnel	U.S. 80 between Benson and Douglas	1,400 ft. (.265 mi.)	1958	1	3	1,300	44	57,200	5,720
California	Wawona Tunnel	Yosemite National Park	4,233 ft. (.800 mi.)	1933	1	2	4,133	28	115,724	11,572
California	Big Oak Flat Tunnel	Yosemite National Park	2,167 ft. (.410 mi.)	1940	1	2	2,067	28	57,876	5,787
California	Broadway Low Level Tunnels	State Highway 24 in Oakland	2,944 ft. (.556 mi.)	1937	2	2	5,688	28	159,264	15,926
California	Caldecott Tunnel	Oakland, companion to Broadway Tunnel	3,000 ft. (.567 mi.)	1964	1	2	2,900	32	92,800	9,280
California	Broadway St. Tunnel	Broadway St. in San Francisco	1,616 ft. (.305 mi.)	1952	2	2	3,032	28	84,896	8,489
California	Randolph Collier Tunnel	U.S. 199 under Hazelview Summit near Oregon State Line	1,835 ft. (.347 mi.)	1963	1	2	1,735	32	55,520	5,552
California	Park Presidio Tunnel	Park Presidio in San Francisco	1,300 ft. (.246 mi.)	about 1940	1	4	1,200	48	57,600	5,760
California	Yerba Buena Tunnel	Through Yerba Buena Island on the San Francisco Bay Bridge (Toll facility)	514 ft. (.097 mi.)	1936*	1	5-upper deck 5-lower deck	828	58	48,024	4,802
California	Waldo Tunnel	North of Golden Gate Bridge on U.S. 101	1,000 ft. (.189 mi.)	1937	1	3	900	38	34,200	3,420
California	Waldo Tunnel Parallel bore	Companion to 1st bore	1,000 ft. (.189 mi.)	1956	1	3	900	38	34,200	3,420
California	Elephant Butte Tunnel	Feather River Canyon Near Plumas	1,187 ft. (.224 mi.)	1937	1	2	1,087	28	30,436	3,043

* R.R. tracks removed in 1961 and lower deck converted to 5 lanes

Part II: LAND TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100[1] per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
California	Underpass	U.S. 40 underpass in Newcastle	531 ft. (.100 mi.)	1932	1	2	431	28	12,068	1,206
California	Underpass	Sepulveda Blvd. under Mulholland Highway in Los Angeles	655 ft. (.124 mi.)	about 1930	1	3	555	38	21,090	2,109
California	Figueroa St. Tunnel	Los Angeles	755 ft. (.143 mi.)	about 1936	1	3	655	38	24,890	2,489
California	Underpass	Sepulveda Blvd. under International Airport in Los Angeles	1,910 ft. (.361 mi.)	1952	2	2	3,620	28	101,360	10,136
Colorado	Mesa Verde Tunnel	Entrance Road to Mesa Verde National Park	1,470 ft. (.278 mi.)	about 1957	1	2	1,370	32	43,840	4,384
Colorado		I-70 near Glenwood Springs	1,045 ft. (.198 mi.)	1965	2	2	1,890	32	60,480	6,048
Colorado		I-70 near Idaho Springs	695 ft. (.131 mi.)	1961	2	2	1,190	32	38,080	3,808
Colorado		I-70 near Idaho Springs	955 ft. westbound (.180 mi.) 875 ft. eastbound (.165 mi.)	1961	2	2	855 755	32 32	27,360 24,160	2,736 2,416
Connecticut	West Rock Tunnel	Wilbur Cross Parkway near New Haven	1,200 ft. (227 mi.)	1949	2	2	2,200	28	61,600	6,160
Massachusetts	Dewey Square Tunnel	John F. Fitzgerald Exp., I-95 Boston	2,400 ft. (.454 mi.)	about 1958	2	3	4,600	44	202,400	20,240
Massachusetts	Prudential Building Tunnel	Under the Prudential Center in Boston (Toll Facility)	1,980 ft. (.374 mi.)	about 1964	2	4	3,760	56	210,560	21,056
New York	1st Avenue Tunnel	Under the United Nations Building Plaza in New York City	1,377 ft. (.260 mi.)	1953	2	2	2,554	28	71,512	7,151
New York	F. D. Roosevelt Drive tunnel	Between 42nd and 48th St. in New York City	1,600 ft. (.302 mi.)	UNK	2	3	3,000	38	114,000	11,400
New York	F. D. Roosevelt Drive tunnel	Between 81st and 89th St. in New York City	2,400 ft. (.454 mi.)	UNK	2	3	4,600	38	174,800	17,480

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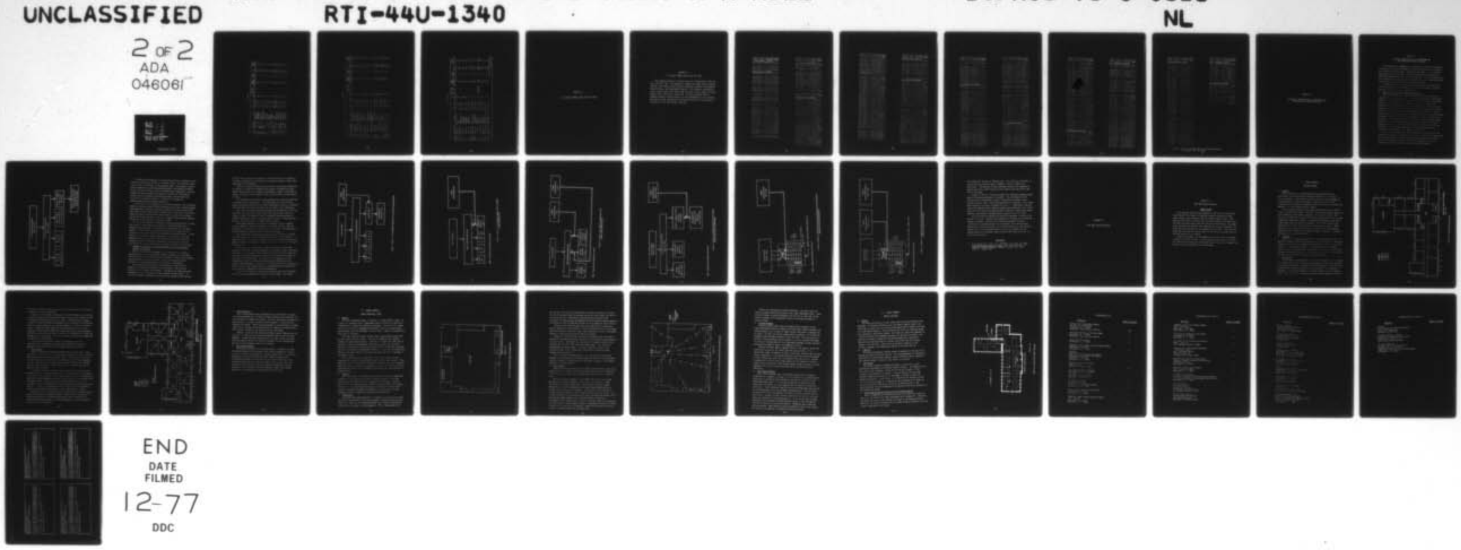

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Part II: LAND TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100 per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
New York	Battery Park Tunnel	Under Battery Park in New York City	2,300 ft. (.435 mi.)	1951	2	2	4,400	28	123,200	12,320
North Carolina	Beaucatcher Tunnel	Through Beaucatcher Mountain in Asheville	1,100 ft. (.208 mi.)	about 1929	1	2	1,000	28	28,000	2,800
North Carolina	Tunnel No. 1 East Bound	I-40 along Pigeon River	1,043 ft. (.197 mi.)	1969	1	2	943	32	30,176	3,017
North Carolina	Tunnel No. 1 West Bound	Companion Tunnel to Tunnel No. 1 East Bound	1,119 ft. (.211 mi.)	1969	1	2	1,019	32	32,608	3,260
North Carolina	Tunnel No. 2	I-40 along Pigeon River	1,198 ft. (.226 mi.)	1969	1	2	1,098	32	35,136	3,513
Oregon	Arch Cape Tunnel	U.S. 101, Oregon Coast Highway	1,228 ft. (.232 mi.)	1937	1	2	1,128	28	31,584	3,158
Oregon	Elk Creek Tunnel	Oregon State Highway 5	1,085 ft. (.205 mi.)	1932	1	2	985	28	27,580	2,758
Pennsylvania	Squirrel Hill Tunnel	Penn-Lincoln Parkway in Pittsburgh	4,225 ft. (.799 mi.)	1953	2	2	8,250	28	231,000	23,100
Pennsylvania	Armstrong Hill Tunnel	Pittsburgh	1,325 ft. (.250 mi.)	UNK	2	2	2,450	28	68,600	6,860
Pennsylvania	Liberty Tubes	Pittsburgh	5,889 ft. (1.115 mi.)	1924	2	2	11,578	28	324,184	32,418
Pennsylvania	Fort Pitt Tunnel	Penn-Lincoln Parkway in Pittsburgh	3,600 ft. (.680 mi.)	1960	2	2	7,000	32	224,000	22,400
Pennsylvania	Allegheny Tunnel	Pennsylvania Turnpike (Toll facility)	6,070 ft. (1.147 mi.)	1940	1	2	5,970	28	167,160	16,716
Pennsylvania	Allegheny Tunnel Parrallel bore	Pennsylvania Turnpike (Toll facility)	6,070 ft. (1.147 mi.)	1965	1	2	5,970	32	191,040	19,104
Pennsylvania	Tuscarora Tunnel	Pennsylvania Turnpike (Toll facility)	5,326 ft. (1.007 mi.)	1940	1	2	5,226	28	146,328	14,632
Pennsylvania	Tuscarora Tunnel Parallel bore	Pennsylvania Turnpike (Toll facility)	5,326 ft. (1.007 mi.)	1968	1	2	5,226	32	167,232	16,723

Part II: LAND TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100' per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
Pennsylvania	Kittatinny Tunnel	Pennsylvania Turnpike (Toll facility)	4,727 ft. (.893 mi.)	1940	1	2	4,627	28	129,556	12,955
Pennsylvania	Kittatinny Tunnel Parallel bore	Pennsylvania Turnpike (Toll facility)	4,727 ft. (.893 mi.)	1958	1	2	4,627	32	148,064	14,806
Pennsylvania	Blue Mountain Tunnel	Pennsylvania Turnpike (Toll facility)	4,339 ft. (.820 mi.)	1940	1	2	4,239	28	118,692	11,869
Pennsylvania	Blue Mountain Tunnel Parallel bore	Pennsylvania Turnpike (Toll facility)	4,339 ft. (.820 mi.)	1968	1	2	4,239	32	135,648	13,564
Pennsylvania	Evans Tunnel	Pennsylvania Turnpike (Toll facility)	4,379 ft. (.828 mi.)	1957	1	2	4,279	32	136,928	13,692
Rhode Island	Converted Streetcar Tunnel	Providence	1,793 ft. (.339 mi.)	about 1955	1	2	1,693	28	47,404	4,740
Tennessee	McCallie Avenue Tunnel	McCallie Avenue through Missionary Ridge in Chattanooga	933 ft. (.176 mi.)	1913	1	2	833	28	23,324	2,332
Tennessee	McCallie Avenue Tunnel, Parallel bore	McCallie Avenue through Missionary Ridge in Chattanooga	1,001 ft. (.189 mi.)	1955	1	2	901	28	25,228	2,522
Tennessee	Bachman Tunnel	U.S. 41 in Chattanooga	1,027 ft. (.194 mi.)	1929	2	2	1,854	28	51,912	5,191
Tennessee	Wilcox Tunnel	Chattanooga	1,312 ft. (.248 mi.)	UNK	1	2	1,212	28	33,936	3,393
Texas	Airport Underpass	Dallas-Ft. Worth Airport	813 ft. (.154 mi.)	about 1963	2	3	1,426	44	62,744	6,274
Utah	Copperfield Tunnel	Bingham Canyon	7,000 ft. (1.323 mi.)	1939	1	1	6,900	18	124,200	12,420
Utah	Zion National Park Tunnel	Zion National Park, State Route 15	5,766 ft. (1.090 mi.)	1936	1	2	5,666	28	158,648	15,864
Washington	Battery St. Tunnel	Seattle	2,140 ft. (.404 mi.)	1953	2	2	4,080	28	114,240	11,424
Washington	Baker Ridge Tunnel	U.S. 10 in Seattle	1,466 ft. (.277 mi.)	1940	2	2	2,732	28	76,496	7,649
Washington, D.C.	Zoo Tunnel	Rock Creek Park	800 ft. (.151 mi.)	1964	1	2	700	32	22,400	2,240

Part II: LAND TUNNELS

State	Name of Tunnel	Location	Length, Portal to Portal	Year Opened	Number of Tunnel Bores	Traffic Lanes Per Bore	Length Available for Shelter Use (Length-100[1]per Bore)	Estimated Width per Bore (Ft.)	Area (Sq. Feet)	Number Shelter Spaces at 10 ft.^{2} per person
Washington, D.C.	12th St. Expressway Tunnel	C St. to Constitution Avenue	533 ft (.101 mi.)	about 1962	1	3	433	44	19,052	1,905
W. Virginia	Wheeling Tunnel	Wheeling	1,485 ft. (.281 mi.)	1966	2	2	2,770	32	88,640	8,864
W. Virginia	Memorial Tunnel	West Virginia Turnpike (Toll Facility)	2,669 ft. (.504 mi.)	1954	1	2	2,569	28	71,932	7,193
Hawaii	Wilson Tunnel	State Route 63 on Island of Oahu	2,780 ft. (.525 mi.)	about 1960	1	2	2,680	32	85,760	8,576
Hawaii	Nuuanu-Pali No. 1	State Route 61 on Island of Oahu	1,000 ft. (.189 mi.)	1957	1	2	900	32	28,800	2,880
Hawaii	Nuuanu-Pali No. 2	State Route 61 on Island of Oahu	500 ft. (.095 mi.)	1957	1	2	400	32	12,800	1,280
Wyoming	Green River Tunnel	I-80	1,137 ft. (.215 mi.)	1966	2	2	2,074	32	66,368	6,636
District of Columbia	9th St. Expressway Tunnel	Constitution Avenue to Interstate Route 95	1,600 ft. (0.303 mi.)	1971	1	3	1,500	44	66,000	6,600
Minnesota	Lowry Hill Tunnel	Interstate Route 94 in Minneapolis	1,500 ft. (0.284 mi.)	1971	2	3	1,400	44	61,600	6,160
Ohio	Lytle Park Tunnel	Interstate Route 71 in Cincinnati	850 ft. (0.161 mi.)	1970	2 bores at 3 lanes 1 bore at 1 lane		1,500 750	44 20	66,000 15,000	6,600 1,500
Oregon	Vista Ridge Tunnel	U.S. Route 26 in Portland	1,100 ft. (0.208 mi.)	1970	2	3	2,000	44	88,000	8,800
Virginia	Big Walker Mountain Tunnel	Interstate Route 77 near Wytheville	4,200 ft. (0.795 mi.)	1972	2	2	8,200	32	262,400	26,240
Nevada	Carlin Canyon Tunnel	15 miles west of the city of Elko on I-80	1,400 ft. (.265 mi.)	1975	2	[illegible]	2,600	32	83,200	8,320
West Virginia	East River Mountain Tunnel	Virginia-West Virginia State line on I-77	5,700 ft. (1.079 mi.)	1974	2	[illegible]	11,200	32	358,400	35,840
									Total Spaces:	1,059,520

Appendix B

U.S. RAILWAY TUNNELS OVER 1,000 FEET LONG

Appendix B

U.S. RAILWAY TUNNELS OVER 1,000 FEET LONG

This appendix contains a listing of the U.S. railway tunnels that are over 1,000 feet long. The tunnels are grouped into eight regions; the New England, Great Lakes, Central Eastern, Pocahontas, Southern, Northwestern, Central Western, and South Western Regions. The following information is given for each tunnel: the tunnel name, location, length, number of tracks, height, width, and type of ventilation. No fallout shelter data is tabulated because railroad tunnels are not recommended for use as shelter. Only when no other alternatives are available should railroad tunnels be included in a host area shelter inventory.

TUNNEL	LOCATION	Length	Trks	Hght.	Wdth	Ventilation
NEW	ENGLAND	REGION.				
Hoosac	North Adams, Mass.	25,081	2	20'	24'	Mech.
Fairhaven	New Haven, Ct	1200	2	18'6"	30'	Shafts
Providence	Providence, R.I.	5079	2	20'6"	30'	Portal
Terryville	Terryville, Ct	3580	2	20'6"	33'	Portal
GREAT	LAKES	REGION				
Susquehanna	Tunnel Sta, N.Y.	2234	1	17'3"	17'5"	Shaft
Old Bergen	Hoboken, N.J.	4283	2	15'10"	26'	Shafts
New Bergen	Hoboken, N.J.	4283	2	17'9"	30'	Shafts
Oxford	Oxford Furnace -	2996	1	15'10"	21'6"	Portal
Roseville	Greendell, N.J.	1040	2	22'10"	30'	Portal
Nicholson	Nicholson, Pa	3629	2	22'6"	29'9"	Shafts
Otisville	Otisville, NY	5314	2	23'	30'	Shaft
Bergen	Jersey City, N.J.	4161	2	20'6"	28'	Shafts
Edgewater	Edgewater, N.J.	5065	2	19'	27'	Shaft
Lansford	Lansford, Pa	3810	1	14'7"	11'	Shaft
Musconetcong	Pattenburg, N.J.	4893	2	25'	30'	Portal
Rockport	Penn Haven Jct. S	1196	2	19'6"	26'	Portal
Vosburg	Tunkhannock Pa	3902	2	19'2"	25'	Portal
Detroit River	Detroit, Mich	8390	2			
Park Ave	G.C.T. New York	10440	4	16' 16' 16'	16' 26' 16'	Shafts
St Marys	Melrose, N.Y.C.	1906	2	16'	26'	Shafts
Weehawken	Weehawken, N.J.	4222	2	16'	26'	Mech
Haverstraw	Haverstraw, NY	1678	2	16'	26'	Portal
West Point	West Point, NY	2740	2	16'	26'	Portal
Cazenovia	Cazenovia, NY	1631	1	16'	16'	Portal
Peale	Peale, Pa	1277	1	17'	16'	Portal
Karthaus	Karthaus, Pa	1431	1	20'	15'	Portal
Deer	Frenchville, Pa	1151	1	20'	16'	Portal
Shawsville	Shawsville, Pa	1792	1	19'	15'	Portal
Fulton	Clearfield, Pa	2716	1	20'	14'	Portal
No 2	Dix, Pa	2193	2	22'6"	29	Portal
No 3	Dix, Pa	1739	2	22'6"	29	Portal
Moxahala	Moxahala, Ohio	1275	1	21'10"	17'3"	Shafts
Koontz Bend	Swiss, W.Va	3163	1	22'4"	18'	Portal
J & L.	Pittsburgh Pa.	1625	2	16'	24'	Portal

TUNNEL	LOCATION	Length	Trks	Hght.	Wdth	Ventilation
Bloomingburg	High View, NY	3856	1	17	13'8"	Portal
Fallsburgh	Fallsburgh, NY	1023	1	17'8"	13'10"	"
Hawks Mt	Cadosia, NY	1130	1	17'4"	13'4"	"
Northfield	Merrickville, NY	1639	1	18'3"	16'	"
Mt Washington	Pittsburgh, Pa	3344	2	22'	27'	Portal
Greentree	Greentree, Pa	4716	2	22'	27'	"
Craighead	Avella, Pa	1163	2	22	27	"
Buxton	Penowa, Pa	1081	2	22	27	"
State Line	Penowa, Pa	1484	2	22	27	"
Fellows	New Alexandria, O	1053	2	22'	27'	"
Hanna	Pittsburgh Jct, O	1525	2	22	27	"
Norris	Norris, Pa	1216	1	21'6"	17'	"
Vang	Baird, Pa	1721	1	21'7"	16'	"
Hamilton	Hamilton, Ont.	1946	2	21'10"	25	Portal
No Bessemer	No Bessemer, Pa	2907	2	19'6"	26'6"	Shaft
Dravosburg	Clarion, Pa	1815	2	28'	31'	Portal
CENTRAL	EASTERN	REGION				
Fairmount Pk	Park Jct, Phil, Pa	2303	2	20'6"	30'	Portal
Howard St	Baltimore, Md	7341	2	18'	29	"
Ilchester	Ilchester, Md	1404	2	23'	30	"
Dorsey	Alberton, Md	1022	2	23'	30'	"
Mt Airy	Mt Airy, Md	2758	2	23'	30	"
Randolph	Orleans Rd, W.Va	1015	2	24'6"	31'	"
Stuart	" " "	3355	2	24'6"	31'	"
Graham	Little Cacapon, W.Va	1592	2	24'6"	31'	"
Knobley	McKenzie, Md	4160	2	23	30	"
Kingwood, old	Tunnelton, W.Va	4154	1	20'	19'	"
" new	" "	4201	2	24'6"	31'	"
No 1	Bridgeport, W.Va	2710	1	17'6"	14	Mech.
No 2	Maken, W.Va	1088	1	18'	14'	Portal
No 6	W Union, W.Va	2297	1	16'9"	14'	"
No 19	Silver Run, W.Va	1494	1	17'3"	14'6"	"
No 21	Eaton, W.Va	2021	1	16'3"	14	Mech
No 2 of Twin	Porters Falls, W.Va	1046	1	18'	16'	Portal
No 3 Summit	Hartzel, W.Va	3215	1	18	16'	Shaft
Board Tree	Board Tree, W.Va	2400	1	16'6"	17	Portal
Welling	Cogley, W.Va	1301	1	18'6"	22'3"	"
No 10 Jacksonville	Emmart, W.Va	1887	1	21'6"	16	"
No 11 Delta	Braxton, W.Va	1121	1	22'	16'	"
Little Otter	Pembroke, W.Va	2358	1	21'6"	15'	"
Flushing	Flushing, Ohio	1545	2	23'	30'	"
Sand Patch	Manila, Pa	4475	2	24'10"	31	Shafts
Pinkerton	Pinkerton, Pa	1081	2	23'6"	28	Portal
Brook	Fort Hill, Pa	1856	1	20'	26	"

TUNNEL	LOCATION	Length	Trks	Hght	Width	Ventilation
[illegible]	Laughlin Jct Pa	2512	2	21'6	26	Portal
Whitehall	Millers Grove, Pa	1630	2	23'	30'	"
Thomas	Thomas, Pa	1050	2	23'6"	30'	"
Brady	Wade, Pa	1737	1	23'3"	26	"
No 6 (Finney)	Sugar Hill Pa	1051	1	21'6"	27'9"	"
Simpson	Horatio, Pa	2324	1	20'0"	16'	"
Empire	Carman, Pa	1018	2	23'9"	30'	"
Sabola	East DuBois, Pa	1551	1	20'8"	16'6"	"
Big (Ritner)	Fort Ritner, Ind	1731	1	21'	30'	"
Willow Valley	Willow Valley, Ind	1160	1	21'6"	18'	"
Hudson River	Penn Term, NYC	5,600	2	16'/16'	19'/19'	Mech.
East River	Penn Term NYC	14172	4	4-16	4-19'	Mech
40th Street	Philadelphia, Pa	1000	2	11'6"	30'	Portal
Union (old)	Baltimore, Md	3405	1	19'6"	24'	"
Union (new)	Baltimore, Md	3333	2	22'3"	33	"
B & P	Baltimore, Md	6994	2	20'9"	27	Mech.
Virginia Av	Washington, DC	3802	1	17'9"	28	Portal
First St EB	Washington, DC	4050	1	16'1"	16'	Mech.
First St WB	Washington, DC	4050	1	16'1"	16'	Mech
Spruce Cr EB	Spruce Creek, Pa	1147	1	20'	28'	Portal
Spruce Cr WB	Spruce Creek, Pa	1075	2	20'	28'	"
Gallitzen Tr 4	Gallitzin, Pa	3595	1	19'5"	17'	Mech.
Gallitzin Tr 3	Gallitzin, Pa	3595	1	19'8"	24'	Portal
New Portage	Gallitzin, Pa	1629	2	19'4"	27'4"	"
Salina	Salina, Pa	1356	2	20	25'	"
East Brady	East Brady, Pa	2462	2	21'2"	30'	"
Woodhill	Woodhill, Pa	2733	1	21'2"	30'	"
Kennerdell	Kennerdell, Pa	3512	1	21'6"	30	"
Summit	Sabula, Pa	1696	1	20'	23'9"	"
Fourth Av	Pittsburgh, Pa	1337	2 [illegible]	17'0"	21'4"	"
Corliss	Pittsburgh Pa	2370	2 [illegible]	19'6"	22'11"	"
Gould	Mingo Jct, Ohio	3320	2	21'8"	25'5"	Mech
Broadacre	Broadacre, Ohio	1345	2	[illegible]	22'11"	Portal
Cadiz Jct	Cadiz Jct Ohio	1331	2	20'9"	22'2"	"
Bowerston	Bowerston, Ohio	1420	2	22'	24'7"	"
Mt Wood	Wheeling, W Va	1226	2	20'9"	26'	"
Chapline Hill	Wheeling, W Va	2278	2	20'9"	26'	"
McLuney	McLuney, Ohio	1166	1	16'1"	14'6"	"
Mineral City	Mineral City, Ohio	1001	1	17'10"	18'7"	"
Tunnel #2	Cincinnati, Ohio	1046	2	19	20'	"
Mahanoy	Mahanoy City Pa	3409	1	16'8"	13'	Mech.
Perkasie	Perkasie, Pa	2142	2	17'	23	Shaft
Phoenixville	Phoenixville, Pa	1932	2	16'5"	25	Shafts
Dillinger	Dillinger, Pa	1193	1	16'6"	13'6"	Portal
Lofty	Lofty, Pa	1025	1	16'7"	13'	"

TUNNEL	LOCATION	Length	Trks	Hght	Width	Ventilation
CENTRAL	EASTERN	REGION				
White Haven	Tunnel Sta Pa	1730	1	18	16'	Shaft
Indigo	Little Orleans W Va	4350	1	20	17'	Portal
Stick Pile	Green Ridge, W Va	1707	1	20	17'	"
Kessler	Kessler, W Va	1844	1	20'	17'	"
Knobley	Maryland Jct, W Va	1449	1	20	17	"
Big Savage	Colmar, Pa	3294	1	20'6"	17	"
No 1	Tunnel, W Va	1716	1	18'6"	13'8"	"
No 2	Glady, W Va	1078	1	18'10"	14	"
Harrisville	Adena, Ohio	1149	1	19'3"	12'6"	Portal
	POCAHONTAS	REGION				
Brookville	Greenwood, Va	1051	1	22'11"	18'	Portal
Blue Ridge	Afton, Va	4263	1	17'6	12	"
Millboro	Millboro, Va	1335	1	18'3"	16	"
Lewis WB (old)	Jerrys Run, Va	4077	1	18'2"	16	Mech.
Lewis EB (new)	Jerrys Run, Va	3055	1	23	18'	Portal
Alleghany	Alleghany, Va	4723	1	18'9"	23'5"	"
Alleghany WB new	Alleghany, Va	4751	1	22'11"	18	"
Second Cr	Rockland, W Va	2067	2	26'6"	32'	"
Big Bend WB old	Hilldale, W Va	65[illegible]	1	18'4"	15'5"	"
Big Bend EB new	Hilldale, W Va	6168	1	23	18'	"
[illegible]	[illegible] W Va	1588	2	26'6"	32	"
Williams Cr	Williams Creek, W Va	2003	1	23'1"	16	"
Big #1	Burks, W Va	1210	1	17'9"	13	"
Seng Creek	Tunnel Siding	3359	1	18'5"	14'8"	"
St Albans	St Albans W Va	1472	1	20'5"	16'	"
Pepper	Cowan, Va	3307	1	20	15	Mech.
Eggleston	Eggleston Va	1176	2	23'5	30'5	Portal
Elkhorn	Coaldale, W Va	7094	1	18	14	Mech
Welch	Welch, W V	1334	2	23'6	28	Portal
Hemphill	Welch, W Va	1150	2	23'6	28	"
Vaughan	Roderfield, W Va	1133	2	23'6	28	"
Gordon	Roderfield, W Va	1268	2	23'6	28	"
Glen Alum	Glen Alum, W Va	1257	2	21	30'6"	"
Big Sandy #1	Kermit, W Va	2626	1	20'	17'	"
Big Sandy #2	Kermit, W Va	1848	1	20'	16'6"	"
Big Sandy #4	Crum, W Va	2060	1	20'	17'	"
Big Sandy #6	Thom, W Va	1800	1	20'	18'9"	"
Big Sandy #7	Thom, W Va	1323	1	20	18'	"
Honaker	Honaker, Va	1060	1	18'	14'	"
Big Bull	[illegible] City Va	1661	1	18'	14'	"
Holbrook	Devina, Va	1576	1	18'	14	"
Little Tom	Fine, Va	1933	1	18'	14	"
Summit	Bonda, Va	4773	1	23	16	"
Stonybrook	[illegible]ville, W Va	4057	1	26'8"	17'	"
Lower Elk	Wiseman, Ky	1691	1	26'8"	17'	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Ventilation
Raitt	Home Creek, Va	3766	1	26 [illegible]	17'	Portal
MP 277.6	Merrimac, Va	5176	1			Portal
MP 325.2	Hales Gap, W Va	1966	1			"
MP 338.5	Oney Gap, W Va	1699	1			"
MP 361.6	Clarks Gap, W Va	1236	2			"
MP 364.6	Micajah, W Va	1273	2			"
Polk Gap	Polk Gap, W Va	2463	1			"
Simon	Simon W Va	1236	1			"
Cub City	Cub City W Va	1115	1			"
Cub City	Cub City W Va	1325	1			"
Justice	Justice W Va	1031	1			"
	SOUTHERN	REGION				
Oak Mt.	Winborn Yd Ala	1197	1	17'6"	16'2"	Portal
Coosa Mt	Dunavent Ala	2431	1	17'3"	15'	"
State Line	Elkhorn City, Ky	1523	1			Portal
Hills Mill	Bartlick, Va	1040	1	21'7"	18'	"
Red Ridge	Steinman, Va	1359	1	21'7"	18'	"
Sandy Ridge	Dante, Va	1854	1	21'7"	18'	"
Townes	Miller Yard, Va	1098	1	21'7"	18'	"
Speers Ferry	Speers Ferry Va	1116	1			"
Clinch Mt	Speers Ferry Va	4135	1	21'7"	18'	"
Indian Ridge	Indian Ridge, Tenn	1023	1	21'7"	18'	"
Blue Ridge	Altapass N C	1865	1	21'7"	18'	"
Uppe Pine Ridge	Switzerland N C	1600	1	21'7"	18'	"
Lower Bridle Path	Switzerland N C	1618	1			"
Lower Pine Ridge	Switzerland N C	2211	1	21'7"	18'	"
Honeycutt	Ashford N C	1688	1	21'7"	18'	"
Marion	Marion N C	1073	1	21'7"	18'	"
Monticello	Monticello, Wis	1217	1	18'6"	13'	Portal
Edgewood #2	Abbott Ill	6594	1	23'2"	18'	"
Edgewood #3	Bristol, Ill	2625	1	21'6"	16'	"
Diana	Diana, Tenn.	1515	1	23'5"	29'	Portal
Blount Sprgs	Blount Sprgs, Ala	1005	2	24'	31'	"
Hayden Mt	Hayden, Ala	2129	2	24'8"	25'	"
Brooks Gap	Parkwood Ala	1055	2	28'	21'3"	"
Lesters	Lesters Tenn	1227	1	18'2"	14'4"	"
Tumlin Gap	Tumlin Gap, Ala	1899	1	16'2"	14'3"	"
Muldraughs	Sparlington, Ky	1856	1	16'3"	12'6"	"
Eastwood	Eastwood Ky.	1026	1	20'3"	16'	"
Pleasant Vly	Pleasant Valley, Ky	1132	1	20'	15'9"	"
Bakers Hill	Ridgetop, Tenn	4618	1	21'6"	18'	"
Chenowee	Chenowee, Ky	1407	1	20'	16'1"	"
Dumont	Dumont, Ky	1013	1	20'4"	16'6"	"
Line	Barwick, Ky	1461	1	20'2"	17'1"	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Ventilation
Hazard	Lennut, Ky	1480	1	20	15'	Portal
Torrent	Torrent, Ky	1115	1	16.3	14'	"
Cumberland Gap	Cumberland Gap, Tenn	3740	1	19'	14	"
Tazewell	Harrowgate, Tenn	1035	1	19'	16'	"
Carwood	Poorville, Ky	1205	1	22'	16'	"
Redwine Gap	Flaxler, Ky	1129	1	22'	16'	"
Hagans	Hagans, Va	6244	1	24'	16'	"
Grant	Ryland Ky	2102 & 2147.5	2 1	20'3"	15'9"	"
Cove Creek	Vasper, Tenn	1697	1	19'0"	15'9"	"
Vasper	Vasper Tenn	1566	1	20	15'6"	"
Dossett	Dossett, Tenn	3533	1	20	15'	"
Copper Ridge	Solway, Tenn	2300	1	20'0"	16'	"
Cumberland Mt	Cowan, Tenn	2217	1	16'11"	12'4"	Shafts
Chattanooga #4	Tunnel Hill Ga	1512	1	22'	16'	Portal
Hardwick	Hardwick, Ala	1370	1	21'	17'	Portal
Rivermont	Lynchburg, Va	1332	2	23'7"	28'3"	Portal
Swannanoa	Ridgecrest, N C	1560	1	16'8"	14'5"	"
Indian Grave	Vasper, Tenn	1489	1	[illegible]	13'1"	"
Elk Gap	Pioneer, Tenn	1150	1	21'4"	14'1"	"
Duncan	Duncan, Ind	4311	1	17'	14'	Shafts
Burton	Norton, Ind	2217	1	21'7"	16	Portal
No 2	Kings Mt Ky	3984	1	17'6"	15'6"	Shafts
No 3	Burnside Ky	1067	1	19'6"	18'5"	Portal
No 4	Burnside Ky	1165	1	21'6"	19'	"
No 7	Greenwood Ky	1160	1	17'8"	15'	"
No 9	Greenwood Ky	1276	1	17'6"	15	"
No 15	Robbins, Tenn	2533	1	18'[illegible]	14'6"	Shaft
No 16	Huffman, Tenn	1083	1	17'6"	15'6"	Portal
No 24	Nemo, Tenn	2031	1	[illegible]	15'6"	"
No 26	Oakdale Tenn	1672	1	17'2"	14'1"	"
Lookout Mt	Chattanooga Tenn	3537	2	23'6"	29'5	Shaft
	NORTHWESTERN	REGION				
Tunnel City	Tunnel City Wis	1330	1	18'5"	14'8"	Portal
Pipestone Pass	Donald, Mont	2290	1	20'2"	16'	"
Blacktail #1	Winfield Mont	1174	1	22'10"	18'5"	"
Garrison	Garrison, Mont	2015	1	20'3"	15'5"	"
Nimrod	Ravenna, Mont	1177	1	20'9"	15'11"	"
St Paul Pass	E Portal Mont	8774	1	20'2"	18'1"	"
Moss Creek	Roland, Idaho	1516	1	20'9"	15'5"	"
Sage Creek	Hoosac, Mont	2014	1	21'	16'6"	"
Watts	Sarrento, Wash	2559	1	20'11"	16'	"
Johnson Cr.	Boylston, Wash	1973	1	21'7"	15'11"	"
Horlick #2	Horlick Wash	1239	1	21'7"	17'8"	"
Snoqualmie	Hyak, Wash	11,890	1	20'1"	15'11"	"
Blue Slide	Blue Slide Wash	1093	1	22'1"	15'11"	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Venti-lation
Winston	Winston, Ill	2493	1	18'3"	12'6"	Mech.
No 2	Pinnacle, Mont	1746	2	26'4	29'	Portal
No 6	Troy, Mont	1390	1	21'6"	16'	"
No 13	Chumstick, Wash	2601	1	20'10	16'	"
No 14	Winton, Wash	4059	1	21'7"	16'	"
Cascade	Berne-Scenic, "	41,152	1	20'10"	16'	"
Everett	Everett, Wash	2440	1	22'	16'	"
Seattle	Seattle, Wash	5142	2	25'8"	30'	"
No 18	Samish, Wash	1113	1	21'2"	16'	"
No 19	Cart[illegible] N D	1456	1	24'3"	19'2"	"
No G-1	S[illegible]	2517	1	21'1"	17'	"
No G-2	[illegible] "	1131	1	22'	16'	"
No G-3	[illegible]	1619	1	22'	16'	"
No G-4	[illegible] "	1569	1	22'	16'	"
No G-5	Wayne "	1162	1	22'	16'	"
Boulder	Amazon "	6145	1	17'8"	15'	"
No 10	Woodville "	1283	1	22'	15'6"	"
No 7	Oroville, Wash	1761	1	22'6	15'4"	"
St Paul	St Paul, Minn	1218	2	29'	34'	Portal
Duluth	Duluth, "	1544	1	20'	16'	"
Bozeman	Muir, Mont	3652	1	20'	16	Portal
Mullan	Blossburg, "	3875	1	20	16'	Mech
Garrison	Garrison "	1394	2	23'4"	28	Portal
Quinns	Quinns, "	1120	1	21'6"	17'	"
Stampede	Martin, Wash	9834	1	20	16'6	Mech
Nelson Bennett	Tacoma "	4391	2	24	28	Portal
Ostrander	Ostrander "	1165	2	24	28	"
Big Horn	Big Horn, Mont	1063	1	20'	16	"
Cape Horn	Cape Horn, Wash	2369	1	22	16'	Portal
No 16	Farrington, "	2494	1	22'	16	"
No 17	Kahlotus "	2220	1	22'	16	"
Ft Wright	Spokane "	2134	1	22	16'	"
Cornelius	Rockton, Ore	4111	1	22	16	"
Tophill	Tophill, "	1136	1	22'	16	"
CENTRAL	WESTERN	REGION				
Raton	Wootton, Colo Lynn, N M	2041E 2785W	1 1	19'0 24	13'10" 16'6	Portal Shafts
No 1	Vine Hill, Calif	1230	1	20	15'	Portal
No 3	Glen Frazer "	5596	1	20'1"	15'2"	"
No 4	Pinole "	1045	1	20'1"	13'5"	"
No 1	Guernsey, Wyo	3334	1	21'5"	17'8"	Portal
No 2	Guernsey, Wyo	1929	1	20'11"	17'	"
No 3	Wendover, Wyo	1442	1	21'8	17'	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Venti-lation
CENTRAL	WESTERN	RE	GI	ON		
No 2	Argyle, Mo	1223	1	22'6"	17	Portal
No 3	Eugene, Mo	1667	1	23	18	"
Tennessee Pass	Tenessee Pass, Colo	2577	1	20'	16'	Portal
Glenwood	Glenwood Sprgs	1227	1	23'	18	"
Sweetwater	Sweetwater, "	1115	1	23'	17	"
Bridgeport	Bridgeport "	2252	1	19	14	"
Altus	Altus, Utah	1132	1	17'	14'	"
No. 10	Plainview, Colo	1570	1	22'	16'	Portal
No 17	Plainview, "	1227	1	22'	16	"
No 19	Crescent "	1045	1	22'	16'	"
No 23	Miramonte "	1602	1	22'	16'	"
No 52	Volcano "	1310	1	22'	16'	"
No 54	Egeria, "	1137	1	22'	16'	"
Moffat	East Portal, "	32,798	1	22'	16'	Mech.
Altamont	Altamont, Calif	1154	1	22	16	Portal
No 6	Summit, "	1653	1 WB	18'2	14'8	Shaft
No 15	Rocklin, "	1505	1 EB	21'0	15	Portal
No 17	Rocklin "	1148	1 EB	21	15'6"	"
No 18	Newcastle "	1000	2	21'	32'	"
No 20	Newcastle "	1248	1 EB	21'2"	16'2"	"
No 21	Auburn, "	1211	1 EB	20'7"	15'2"	"
No 28	Applegate, "	3209	1 EB	20'7	15'2"	"
No 29	Applegate "	1009	1 EB	21	15'2"	"
No 33	Cape Horn "	1231	1 WB	21	32'	"
No 41	Norden, "	10,326	1 EB	22'	17	"
No 4	Elmore, "	1785	1	22'	17	"
No 1	Perris "	2070	1	21'2	17'	"
No 2	Calor, Ore	1145	1	21'2	17	"
No 13	Siskiyou, "	3108	1	18'	14	"
No 14	Wall Creek, "	1192	1	16'7"	15	"
No 2	Tonka, Ore	1903	1 WB	20'9	16'4"	"
No 3	Ryndon, "	2417	1 WB	21'	16'4"	"
No 4	Ryndon "	3926	1 WB	20'0	16'6	"
No 5	Ryndon, "	1655	1 WB	21'3	17'	"
No 3	Cascade Summit, Ore	3655	1	21'	17'	"
No 7	Crozatte, Ore	3164	1	22'	16'8"	"
No 9	Crozatte, "	1144	1	22'	16	"
No 14	Frazier, "	2121	1	22'	16'	"
No 16	Fields, "	2213	1	22	16'9"	"
No 22	Oakridge, "	1999	1	20'11"	16'10	"
No 8	Glendale, "	2811	1	17'8"	13'10"	"
No 9	Hugo, "	2105	1	18'8"	15'4"	"
No 13	Vaughn, "	2489	1	20'11"	15'8"	"
No 15	Canary, "	2133	1	21'2"	16'11"	"
No 17	Ada, "	1200	1	21'4"	16'1"	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Ventilation
CENTRAL	WESTERN	REGION				
No. 18	Brenham, Ore	[illegible]	1	21	16'	Portal
No 19	Tharp "	4183	1	21'5	16	"
No 25	Strassel "	1417	1	22	16	"
No 38	Riverwood "	1396	1	23'6"	18	"
No 1	San Francisco	1817	2	21'6"	29'5	"
No 2	San Francisco	1086	2	21'11"	29'5	"
No 3	San Francisco	2364	2	21'6"	29'8	"
No 4	Bayshore, Calif	3547	2	21'	28'2"	"
No 5	Visitacion "	1134	2	21'8"	29'4	"
No 5½	Metz "	1705	1	22'	17'	"
No 6	Cuesta "	3610	1	17'9	15	"
No 7	Tule "	1354	1	18'2"	15'2	"
No 1	Wrights "	6207	1	19'9	15'7"	"
No 2	Glenwood	5792	1	19'7	15'3	"
No 5	Bealville "	1170	1	22	16'6	"
No 29	Searles "	4340	1	21'2"	17'	"
No 25	Tunnel "	6976	1	22	16	"
No 26	Hasson "	7369	1	20'2"	16'	"
Rio Grande	Bowen NY	1020	1	19'10"	15'8	"
No. 2	Reed, Calif	1853	1	17'	22'4	Portal
No 3	Greenbrae, "	1105	2	30	23'6"	"
No 4	Cerro "	1359	1	17	22'4"	"
No 6	Preston, "	1762	1	18	17'9"	"
No 8	Thorn, "	1270	1	18'2"	16'2"	"
No 27	Island Mt. "	433	1	17	21'8"	"
No 38	Larabee "	1122	1	17	21'4	"
No 39	Camp Nine, "	1029	1	15	19	"
No 40	Table Bluff "	969	1	12'6	17'	"
No 1	Alto, "	219	1	14	16'4	"
No 8	Carriso Gorge, Calif	2527	1	21'8"	7'9	Portal
No 14	Carriso Gorge "	2597	1	21'	8'6"	"
Sherman EB	Hermosa, Wyo	1801	1	24	16'	Portal
Sherman WB	Hermosa, Wyo	1828	1	24	16'	"
Aspen	Aspen, Wyo	5941	1	18'3"	16	"
No 3 EB	Wahsatch Utah	1530	1	23'6"	16'	"
No 4 EB	Wahsatch, Utah	1106	1	23'6	16'	"
No 6 EB	Curvo Utah	1223	1	23'6	16'	"
Hodges Pass	Moyer Jct Wyo	1426	1	20'6"	16	"
No 6	Nampers Ore	2538	1	21'6	17'	"
No 18	Pramola Jct Ore	5420	1	21'	16'	"
No 8	Page Wash	1013	1	20'6"	16'6"	"
No 11	Joso, Wash	1760	1	22'	15'3"	"
No 4	Kyle, Nev	1226	2	25'6"	30'7"	"
No 11	Eccles, Nev	1324	2	25'6"	32'	"

TUNNEL	LOCATION	Length	Trks	Hght.	Width	Ventilation
CENTRAL	WESTERN	REGION				
A	San Francisco (Frt Depot)	1625	1	21	16'6	Portal
No 1	Niles, Calif	4321	1	21'	16'6"	"
No 23	Belden, "	1258	1	21	16'6	"
No 33	Keddie, "	1172	1	21	16'6	"
No 35	Spring Garden, "	7335	1	21	16'6"	"
No 6	Mohala "	1103	1	22'4	18'	"
No 37	Chilcoot, "	6001	1	21'	16'6"	"
No 39	Cluro, Nev	1061	1	21'	16'6"	"
No 41	Carlin, "	2342	1	21'	16'6"	"
No 42	Hunter "	1072	1	21'	16'6	"
No 43	Jasper, "	5676	1	21	16'6"	"
SOUTH	WESTERN	REGION				
Gray Summit	Gray Summit, Mo	1580	2	24'0"		Portal
Reeds Spring	Reeds Spr Mo	2356	1	21'6"		"
Crest	Crest, Ark	3455	1	21		"
Cricket	Cricket, Ark	2657	1	19'11"		"
Cotter	Cotter, Ark	1034	1	22'2"		"
Conway	Conway Ark	409	1	20'7"		"
Winslow	Winslow, Ark	1706	1	18'6"	13'6"	Portal
Jenson	Jenson Ark	1191	1	19'	13'6"	"
St Louis	St Louis, Mo	4425	2	16' 16	14 13'	Mech.

Source: AREA Proceedings, American Railway Engineering Association. Vol. 41, 1940.

Appendix C

ELECTRICAL POWER FOR CRISIS ILLUMINATION AND VENTILATION IN EXISTING BUILDINGS

Appendix C

ELECTRICAL POWER FOR CRISIS ILLUMINATION AND VENTILATION IN EXISTING BUILDINGS

The purpose of this appendix is to show how the electrical systems of an existing building can be adapted so that the building can be used as a civil defense fallout shelter. In previous work (Ref. 1), it has been demonstrated that a mine with a drift entrance can be illuminated and ventilated adequately for use as a fallout shelter. The techniques used in the illumination and ventilation of a mine are similar to those applied to the illumination and ventilation of existing buildings.

No portion of the electrical system that operates above 600 volts will be considered in this appendix. It is assumed that the voltage of the service entrance is less than 600 volts.

A. <u>The Electrical Systems of Existing Buildings</u>

The current practice in commercial electrical power distribution systems is to use a 480/277-volt, three-phase, wye-connected distribution system in all but very small buildings. A flow chart of a representative system is shown in Figure C-1. Most motor and heating loads in the building are three-phase, 480-volt devices that can be connected to the supply without transformation. Most luminaires are single-phase 277-volt devices that are distributed among the three-phase conductors. Small, portable appliances that require a single-phase, 120-volt electrical supply are supplied power through auxiliary transformers located throughout the building. These transformers have a 480/277-volt, wye-connected, three-phase primary circuit and a 208/120-volt, wye-connected, three-phase secondary circuit. In some small buildings all electrical circuits are 208/120-volt, three-phase, wye-connected circuits, eliminating the intermediate transformation to a 480/277-volt service.

A few older buildings still have an electrical service of 240/120-volts, three-phase, with an open-delta connection. While this service used to be popular because only two single-phase transformers were needed to provide a three-phase load, only an old building whose load has not increased significantly would be likely to have such service.

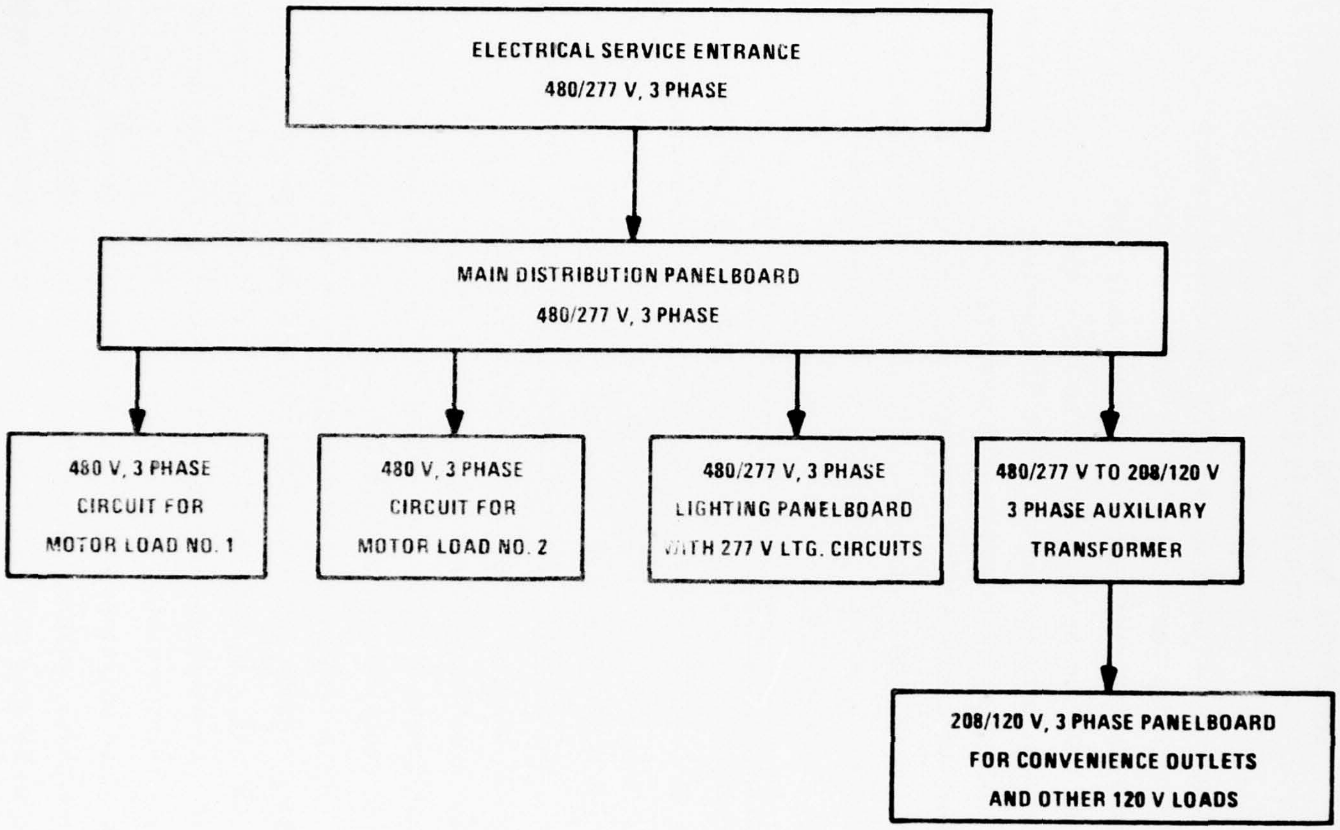


FIGURE C-1. FLOW CHART OF A REPRESENTATIVE ELECTRICAL DISTRIBUTION SYSTEM IN A COMMERCIAL BUILDING

A standby engine-generator in an existing building is connected to the electrical distribution system by a transfer switch. The transfer switch can be either of the manual or the automatic type. The automatic transfer switch automatically starts the engine-generator and transfers selected portions of the building's load to the standby engine-generator. Usually, automatic transfer switches are installed in electrical distribution systems that are operated by untrained personnel, and the electrical circuits are connected so that it is impossible to damage the engine-generator through improper operation.

In buildings that are maintained by trained personnel, such as heating plants or factories, manual transfer switches may be used. Because standby engine-generators seldom can handle the capacity of an entire plant, the operating personnel usually must disconnect part of the load in a building before the manual transfer switch can be used to connect the building's load to the engine-generator. The use of a manual transfer switch provides flexibility in the selection of electrical loads.

If a building contains a stationary standby engine-generator, a survey must be made to determine if the capacity of the engine-generator is adequate to provide power for the existing illumination and ventilation systems. If the capacity of the engine-generator is adequate for all anticipated loads, the system can be operated without modification. If the capacity is inadequate, enough loads must be disconnected so that the generator cannot be overloaded. Disconnections can be made either by detaching electrical cables and taping bare conductors or by setting circuit breakers in the "off" position and applying tape or warning tags.

B. <u>Temporary Connection of an Engine-Generator to the Distribution System of a Building</u>

When no provision has been made for the connection of a standby engine-generator to the distribution system, a procedure of three steps must be followed. First, the load must be analyzed. Second, the available engine-generators must be classified. Third, the optimum method of connecting the engine-generators to the load must be determined.

The analysis of the load must be based on the devices that are expected to be operated during the crisis situation. These devices primarily will be lights and fan motors. The operating voltage and power consumption must be determined from the nameplate of each device. In recording the power consumption of a device, the wattage of each lamp and

the full load current of each motor will usually be easiest to determine. The power consumption of the ballasts of fluorescent lamps or metal vapor lamps must not be neglected.

After the loads are classified, the existing distribution system must be charted. A single-line diagram of the existing distribution system should be made as an aid in planning the emergency system. Disconnection points, including circuit breakers, fuses, and disconnect switches should be shown.

The engine-generators that are available must be classified according to voltage, phase, and capacity. The engine-generators that are most readily available probably will be small single-phase, 120-volt or 240/120-volt, portable units with load capacities not greater than 5,000 watts.

The larger, three-phase engine-generators may be mounted on a trailer. Therefore, they may not be usable unless they can be moved inside the fallout shelter. Occasionally, small three-phase engine-generators of 5,000-to 20,000-watt capacity are used, and this size of engine-generator would be especially useful in a small fallout shelter.

Three-phase generators are capable of operation either at 480/277 volts or 208/120. Generators operating in the lower voltage range can be adjusted for operation at 208/120 volts or 240 volts. Some generators can be connected to operate at any of the above voltages.

The method used to connect the engine-generators that are available will depend upon the loads to be served and the type of distribution system available. Six special cases can be used to illustrate many of the possible methods of connection. These six cases are illustrated in Figure C-2 through C-7.

Three cases are illustrated in Figure C-1 through C-3 where the engine-generators and loads are compatible in voltage and phase connection. In Figure C-2, the transfer switch connects the portion of the electrical load needed for operation during a failure of the normal power supply to the standby engine-generator. In Figure C-3, the emergency load is disconnected from the distribution panelboard and reconnected to the standby engine-generator. In Figure C-4, a situation similar to Figure C-3 occurs, but here two separate loads are disconnected from the panelboard and separately reconnected to two engine-generators.

Figure C-5 illustrates a special case where an auxiliary transformer can be used to feed power to the circuits of a building. The standby

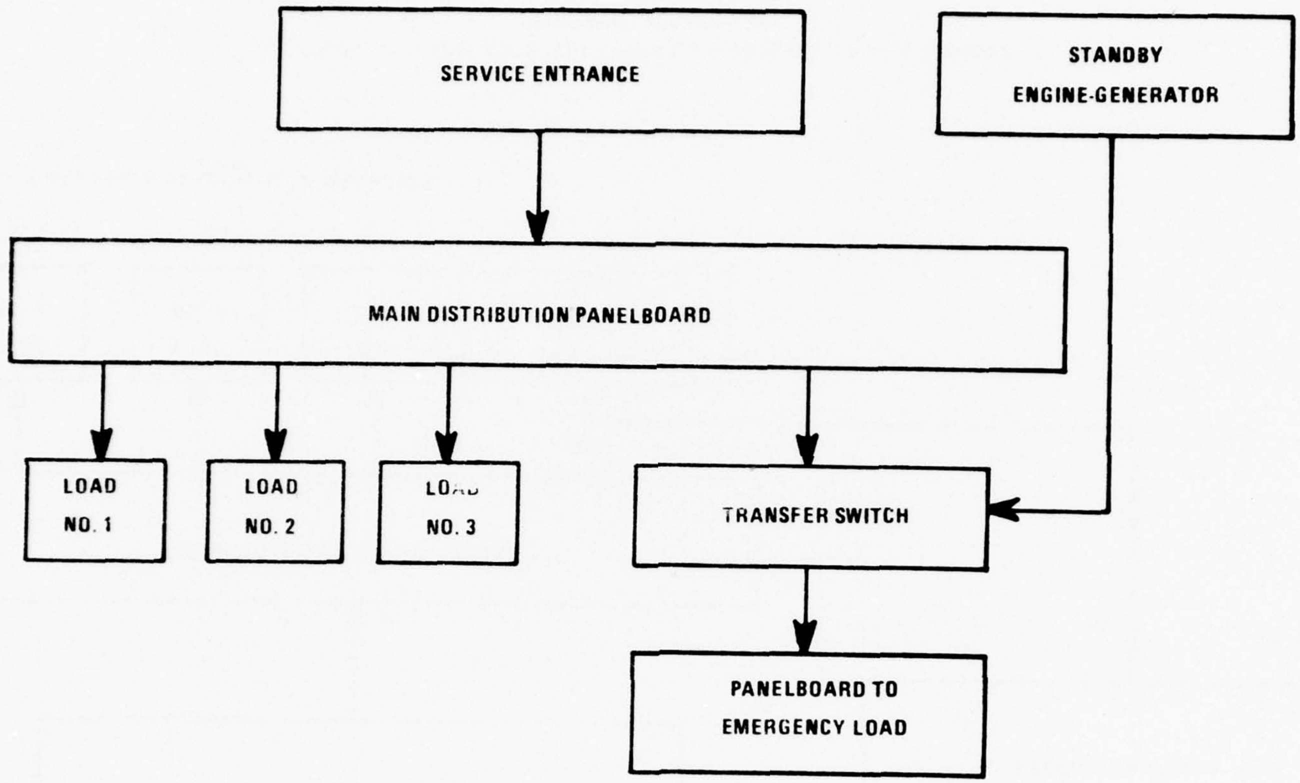
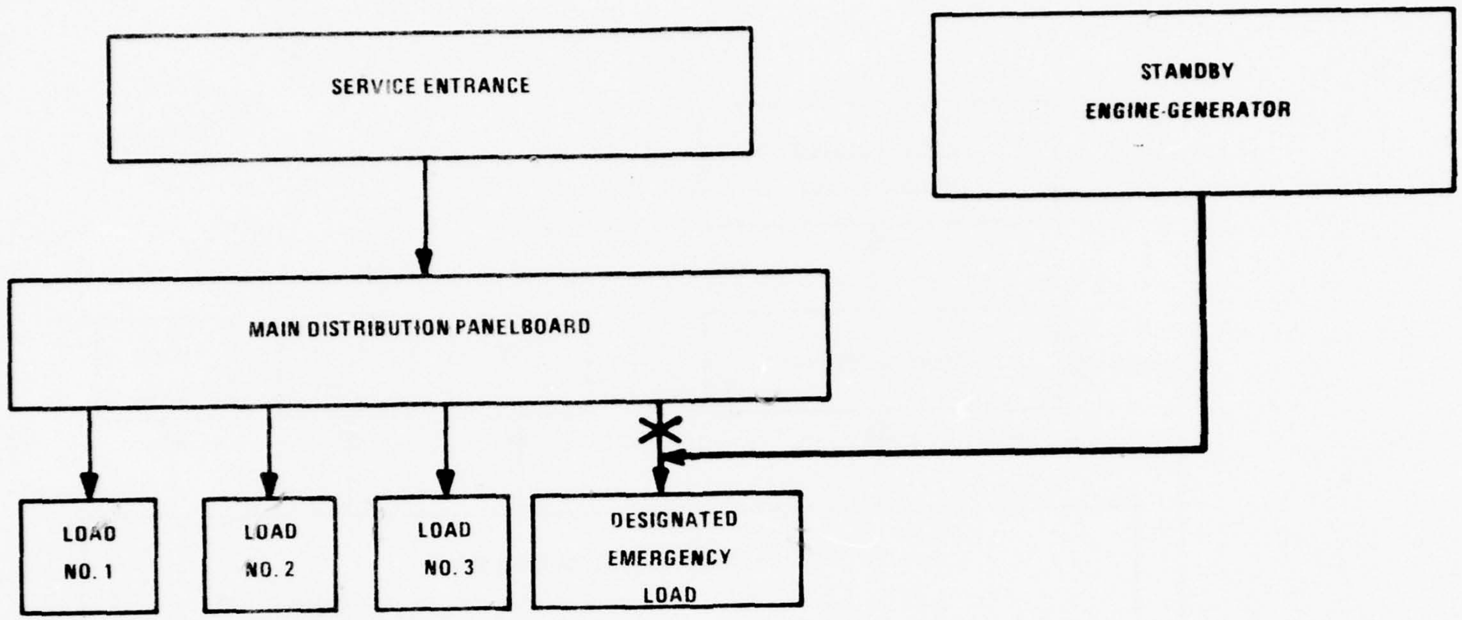
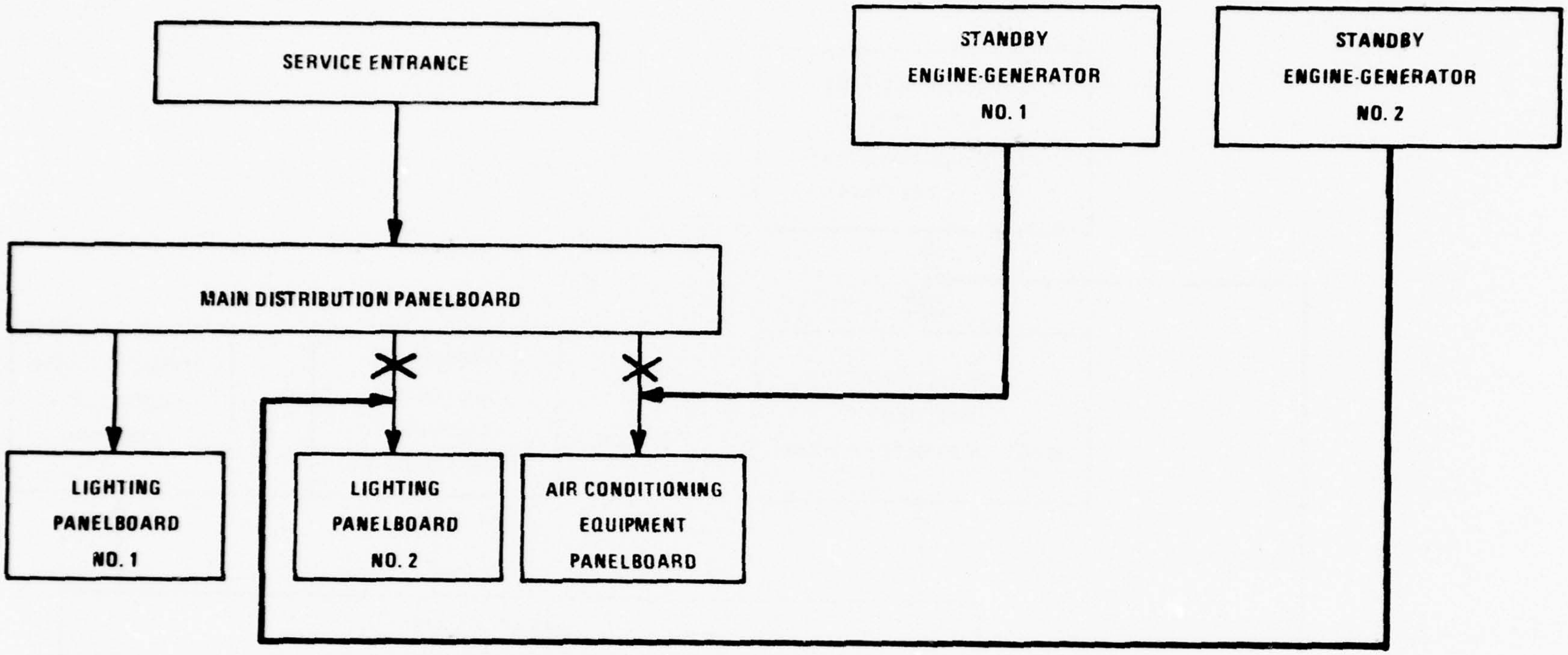


FIGURE C-2. CASE NO. 1: THE PERMANENT CONNECTION OF A STANDBY ENGINE-GENERATOR



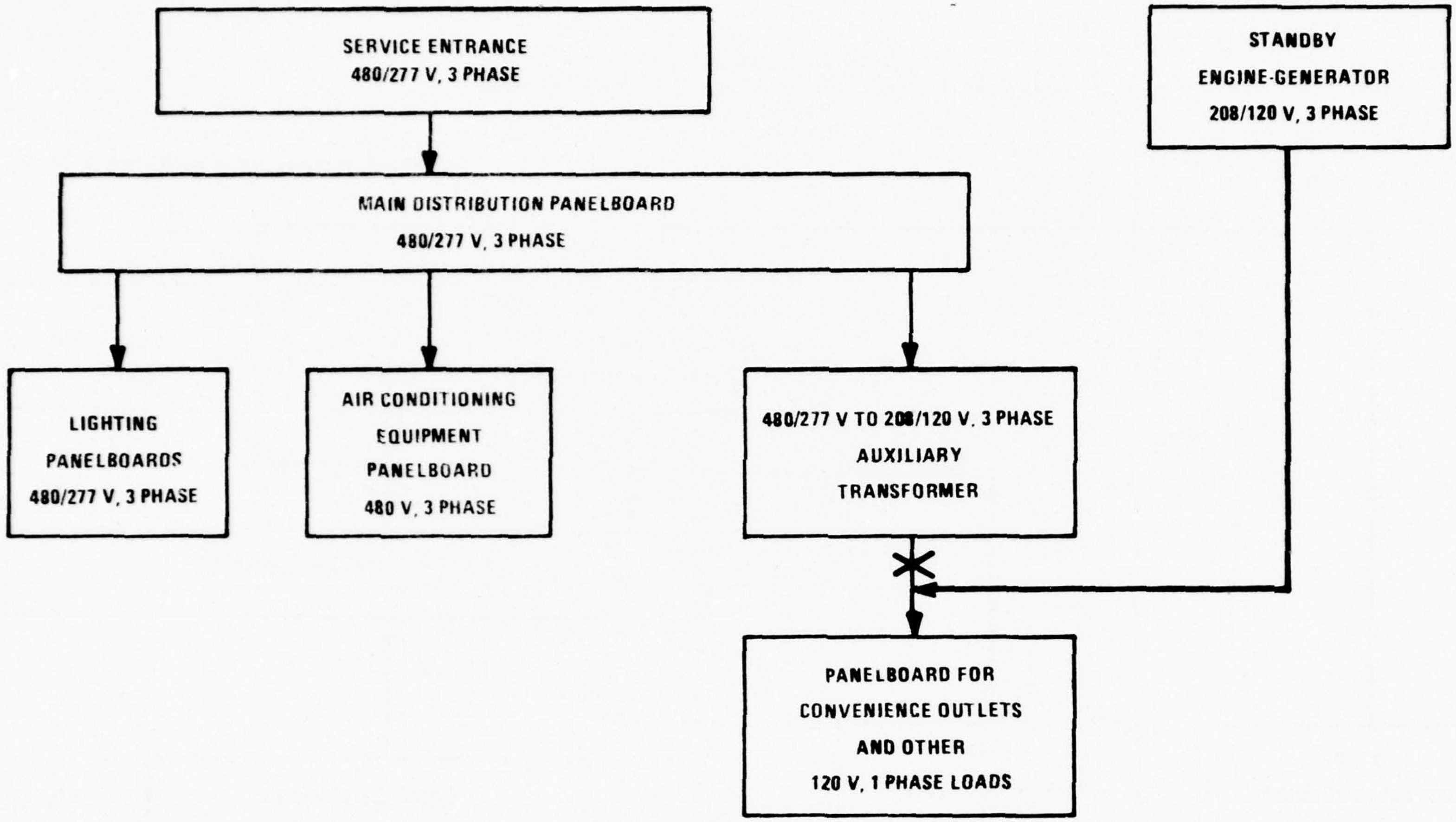
NOTE: X means secure circuit breaker in open position.

FIGURE C-3. CASE NO. 2: THE TEMPORARY CONNECTION OF A STANDBY ENGINE-GENERATOR SET



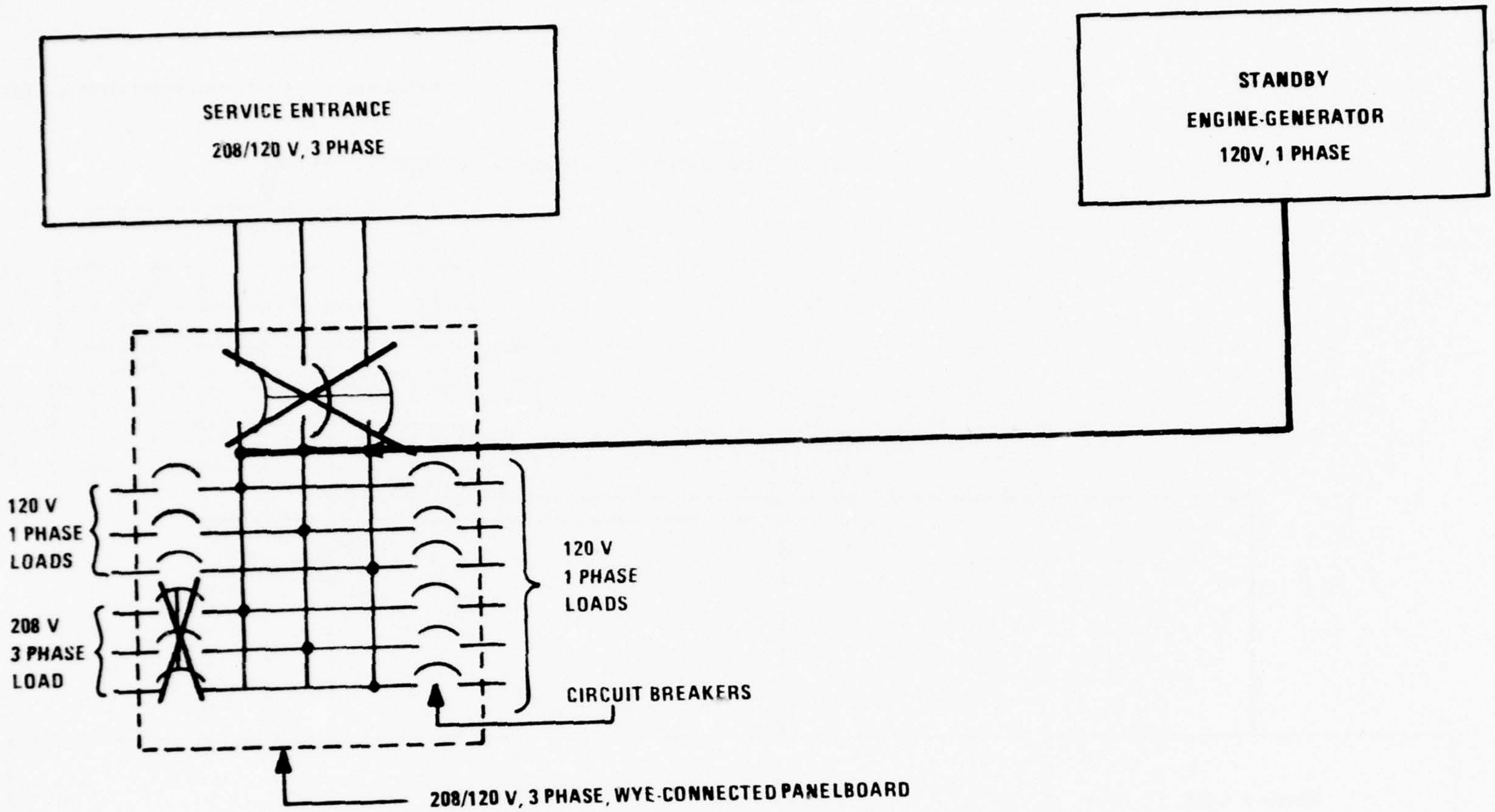
NOTE: X means secure circuit breaker in open position.

FIGURE C-4. CASE NO. 3: THE TEMPORARY CONNECTION OF TWO STANDBY ENGINE-GENERATOR SETS



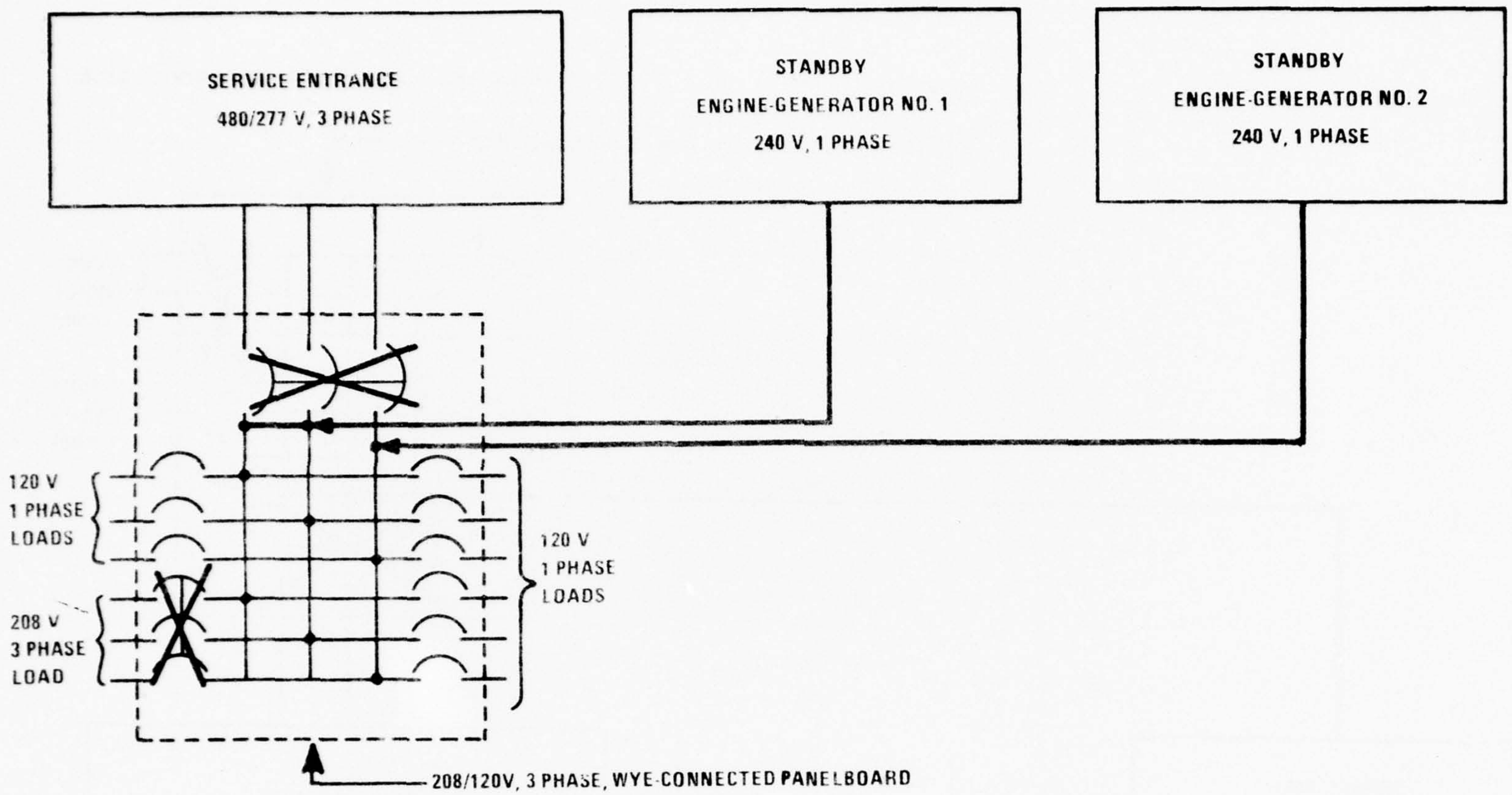
NOTE: *X means secure circuit breaker in open position.*

FIGURE C-5. CASE NO. 4: THE DISTRIBUTION OF ELECTRICAL POWER THROUGH AN AUXILIARY TRANSFORMER



NOTE: X means secure circuit breaker in open position.

FIGURE C-6. CASE NO. 5: *FEEDING* SINGLE-PHASE LOADS FROM A SINGLE PHASE-GENERATOR THROUGH A THREE-PHASE PANELBOARD



NOTE: *X means secure circuit breaker in open position.*

FIGURE C-7. CASE NO. 6: FEEDING SINGLE-PHASE LOADS FROM TWO SINGLE-PHASE GENERATORS THROUGH A THREE-PHASE PANELBOARD

engine-generator operates at 208/120 volts. The auxiliary transformer is used to provide electrical power at 480/277 volts for lighting and ventilation. The capacity of the transformer should not be expected to provide more than a small fraction of the lighting and ventilation load within a building.

Figures C-6 and C-7 illustrate a method for supplying emergency power when no three-phase generator is available. The three-phase service entrance and all three-phase loads are disconnected; no power can be provided to these loads. Each engine-generator is connected to one or more phase conductors as shown in Figures C-6 and C-7. Single-phase, 120-volt loads can be powered from a 120-volt standby engine-generator; and, single-phase, 277-volt loads can be powered from a 240-volt, single-phase engine-generator operating at a maximum output voltage not over 277 volts.

Safe and effective operation of electrical equipment is difficult to achieve in a crisis situation when temporary modification of the existing system is required. Access to all electrical equipment should be restricted to trained personnel with a knowledge of the modifications. Modifications should be labeled. As a minimum precaution, tape should be placed over a circuit breaker when it is not to be operated and the operating arm of a disconnect switch should be held open with wire if a lock is not available.

References

1. M. D. Wright, E. L. Hill, J. S. McKnight, S. B. York, III, Mine Lighting and Ventilation in Crises, Final Report 43U-982-1. Research Triangle Institute: Research Triangle Park, North Carolina. October 1975.

Appendix D

HOST AREA SHELTER SERVICES

Appendix D

HOST AREA SHELTER SERVICES

EXAMPLE PLANS

This appendix contains three examples of the use of the guidelines established in this report to formulate lighting, ventilation, water supply, human excreta disposal, and solid waste disposal plans. Each building floor plan is derived from a building surveyed in the NSS, with additions and modifications made for the sake of the example. An example of one building from each of three different use classes; government and public services, educational, and commercial is included. These were the three most prevalent use classes found in the four-county sample from the CRP Host Areas Facility Listing.

Service requirements in the examples are calculated for the maximum in-shelter period of 14 days. In most cases, the stay time will be much less than this (an average of about seven days); however, the examples are used to illustrate the most severe requirements.

I. EXAMPLE NUMBER 1

(MADISON SCHOOL)

A. General

Madison School is a rural New England high school which was constructed in 1923 and contains grades 10 through 12. It consists of 16 classrooms, 2 offices and 1 cafeteria which is fully equipped for food preparation. Figure D-1 presents a floor plan of the school. A separate building houses the gymnasium and also serves as an auditorium. However, it is not included in this example.

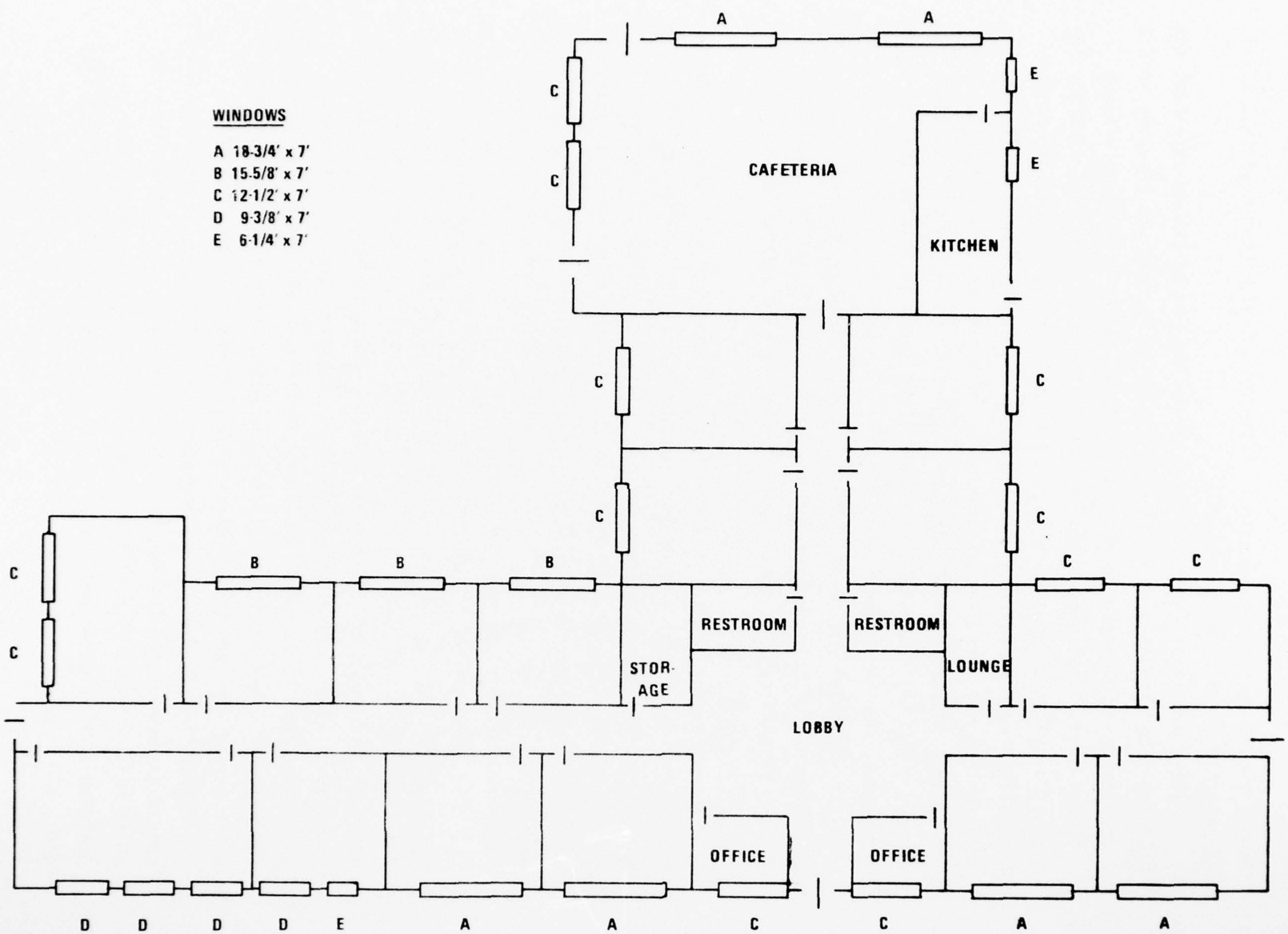
The classroom building contains approximately 15,630 square feet of floor area usable for shelter. Therefore, at 10 square feet per person, it will accommodate 1,563 shelter occupants in a crisis situation. The building currently has an artificial lighting system, but it does not have a mechanical ventilation system. The exterior wall aperture area totals 2,559 square feet, not including doorways. The building contains two restrooms with a total of 10 toilets, 4 urinals, and 4 faucets. Other watering points include 3 water fountains, 20 faucets in the chemistry laboratory, and 2 faucets in the cafteria kitchen. Garbage is collected twice weekly by a municipal service.

B. Lighting

The artificial lighting system which illuminates Madison School is more than adequate for the building's use as a fallout shelter. Only about 5 percent (or less) of the system's total capacity is needed in a crisis situation. Since emergency power is not available on site, portable engine-generators of appropriate capacity and voltage must be located and arrangements made for their use. An experienced electrician or electrical engineer should determine the power and voltage required.

C. Ventilation

Madison School can accommodate 1,563 shelter occupants. It is located in a county having a zonal ventilation requirement of 10 cfm per occupant for temperature control. Therefore, the design capacity of the ventilation system should be 15,630 cfm (1,563 shelter occupants x 10 cfm/shelter occupant). One industrial-type fan or several smaller fans will provide this volume of air flow. Ideally, fans with a rated capacity as close to



UNMARKED ROOMS ARE CLASSROOMS.

SCALE 1″=25′

FIGURE D-1. FLOOR PLAN OF MADISON SCHOOL

15,630 cfm as possible should be used since no significant head loss would be expected in this configuration.

Figure D-2 illustrates the location of the fan to exhaust air from the building, the path of airflow through the building, and the location of the 2 doorways and 20 windows used as air inlets. Because the open windows are well distributed around the periphery of the building, air distribution with this system should not be a problem; however, if further air distribution is required, Kearny pumps should be considered for use. It is important to note that the heaping of earth about the building to upgrade the fallout protection could make it difficult (or impossible) to leave the windows open as illustrated. If this is the case, an alternative method of ventilation may be necessary.

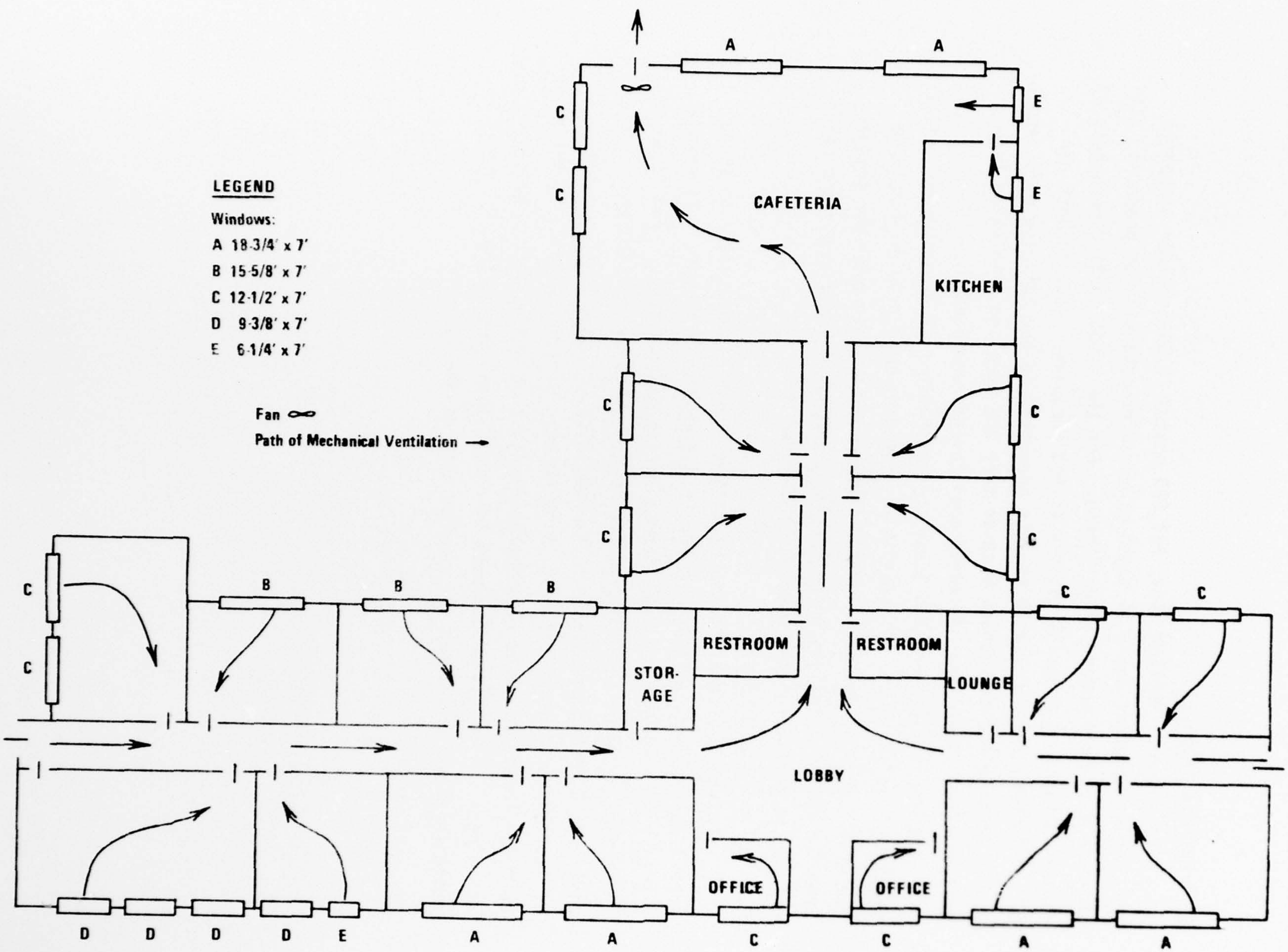
The fan should be mounted rigidly in the doorway, and the engine-generator to power the fan should be located just inside the doorway so that exhaust fumes will be drawn outside the building.

D. Water Supply

Water is supplied to the Madison School from a private well. Since this source is on-site and is protected from radioactive fallout, it should provide potable water during a nuclear crisis. The capacity of the well is 25 gallons per minute and there are 15,000 gallons of storage capacity on site. Therefore, over a 2-week period, there are potentially 519,000 gallons (15,000 gallons + 25 gallons per minute x 20,160 minutes per 14 days) of water available.

The amount of water required for the 1,563 shelter occupants of the Madison School for a 14-days shelter stay is 8,284 gallons (1,563 occupants x 5.3 gallons per occupant). This is only a small fraction of the amount of water that can be supplied by the well and, consequently, there should be no shortage of water. In fact, a more than adequate amount of water is available from the storage tank alone without pumping additional water from the well. However, in this building there is the possibility that water usage may be limited by the capacity of the sewage disposal system.

Using the ratio of 1 watering point per 100 people, 16 watering points should be provided in the Madison School. However, due to the manner in which this facility is partitioned into rooms, greater convenience is achieved with 18 water points, 1 in each classroom, 1 in the lobby-office area, and 1 in the cafeteria.



UNMARKED ROOMS ARE CLASSROOMS.
SCALE 1"=25'

FIGURE D-2. FLOW OF VENTILATION THROUGH MADISON SCHOOL

E. Excreta Disposal

Over a 2-week shelter stay, 984,690 ounces (1,563 shelter occupants x 45 ounces/occupant day x 14 days) of human excreta will be produced, all of which must be disposed of or stored. For the 1,563 shelter occupants of Madison School, at least 32 toilets (1,563 occupants x .02 toilets per occupant) are needed. The 10 toilets presently in the building will remain usable after a nuclear attack because they are supplied with water from a well on-site. Therefore, 22 additional toilets are needed.

Chemical toilets are the least objectionable type of temporary toilet facility. If these are not available, removable pail privies should be employed. A pump should be located that can be used to pump the sewage from the chemical toilets or collection container for the removable pail privies to earth trenches outside of the shelter.

F. Solid Waste Disposal

Solid waste production in the Madison School is estimated to range from 32,823 pounds to 54,705 pounds (1,563 shelter occupants x 14 days x 1.5 to 2.5 pounds/occupant day) for a 14-day shelter stay. From 47 to 63 containers of 26-gallon capacity (or less) should be provided and distributed throughout the facility for solid waste collection. The collection containers will need to be emptied once or twice daily into central storage containers, which may consist of empty water storage containers. When radiation drops to permissible levels, the storage containers can be emptied in trenches outside the building.

II. EXAMPLE NUMBER 2

(S-MART DEPARTMENT STORE)

A. General

The S-Mart Department Store is located in a Middle Atlantic state. It is part of a regional chain of department stores and carries a diverse mix of merchandise, ranging from clothing to hardware. It consists of a large floor area divided into departments by counters, shelves, low partitions, and stockrooms about the perimeter of the building. Figure D-3 presents the floor plan of the store.

The S-Mart Department Store contains approximately 86,050 square feet of floor area usable for shelter. This will accommodate 8,605 people, allowing 10 square feet per person. The store is lighted and ventilated by artificial lighting and mechanical ventilation systems. During normal operation, the mechanical ventilation system delivers 30,000 cfm of outside air, but if converted to 100 percent outside air it will deliver 120,000 cfm. There are 370 square feet of window area and 688 square feet of doorways in the exterior walls.

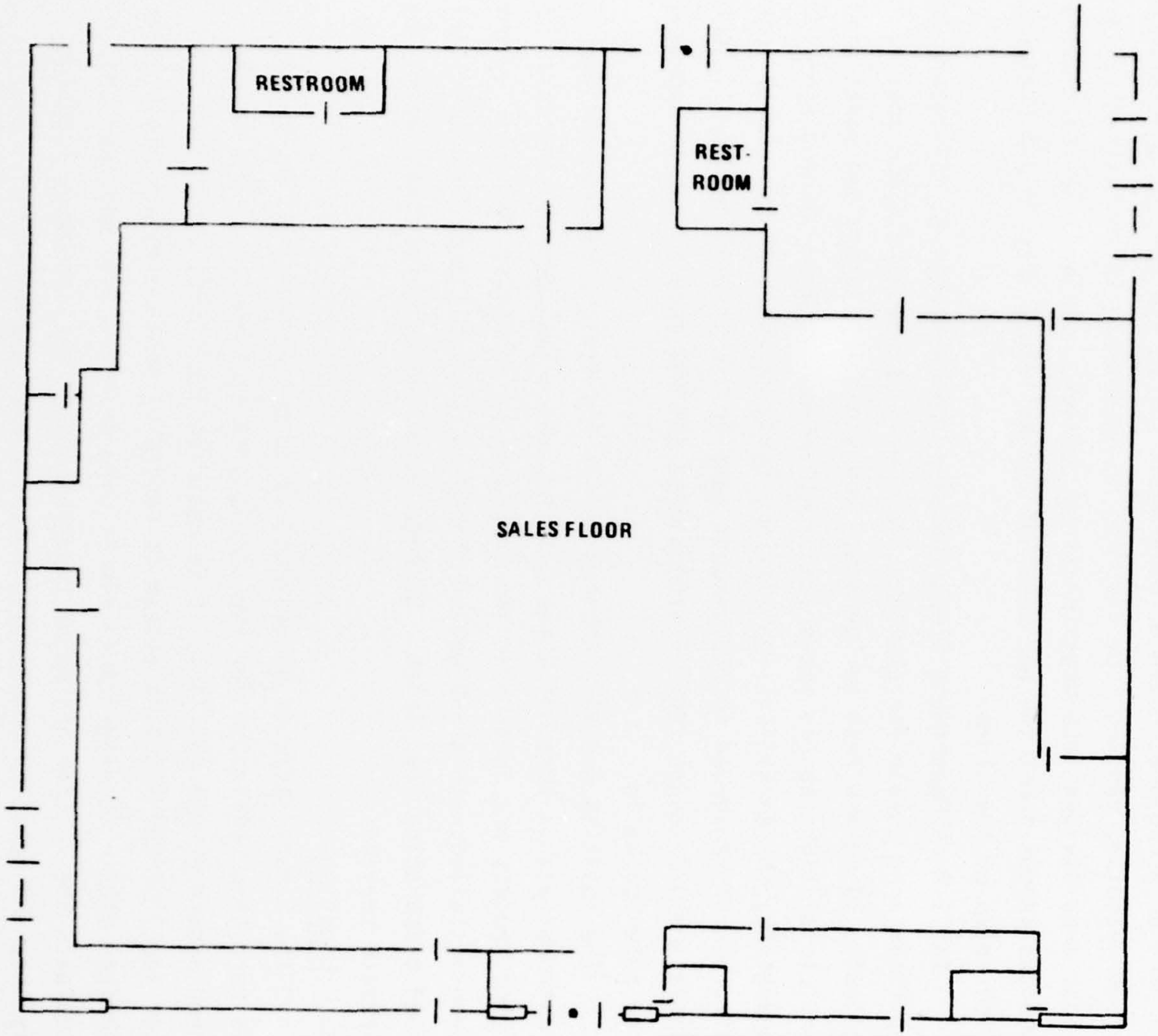
The building contains limited toilet facilities, having only two restrooms with a total of three toilets, one urinal and two faucets. Three other faucets are located in the store and an automatic sprinkler system has been installed with a 650 gallon standpipe. A small grill provides limited food preparation facilities. Garbage is collected three times weekly by a private service.

B. Lighting

The S-Mart store is illuminated by an artificial lighting system that is more than sufficient for the use in a fallout shelter. Due to the open nature of the facility, it is estimated that only about 3 percent (or less) of the lighting system is needed to provide enough light during a shelter stay. An experienced electrician or electrical engineer should evaluate the voltage and power requirements of the emergency lighting systems and identify compatible, portable engine-generators.

C. Ventilation

Since the S-Mart Department Store is located in a county with a zonal ventilation requirement of 20 cfm per occupant, the design capacity of the ventilation system for the S-Mart Department Store should be 161,300 cfm (8,065 shelter occupants x 20 cfm/occupant). This is approximately 34



UNMARKED ROOMS ARE FOR STORAGE.

SCALE 1"=27'

FIGURE D-3. FLOOR PLAN OF S-MART DEPARTMENT STORE

percent more than the existing mechanical ventilation system will provide. The existing system should be adequate during the winter months and most of the spring and fall; nonetheless, planning should cover worst-case situations and require that an expedient forced ventilation system capable of delivering at least 161,300 cfm of fresh air be designed for this building.

Three to five industrial-type fans are estimated to be required to deliver 161,300 cfm of ventilation. Since no significant loss of efficiency should be incurred, fans with a total rated capacity as close to the design capacity of the system as possible should be located.

Figure D-4 illustrates the location of the exhaust fans, the path of ventilation through the building, and the six doors and two windows used for fresh air inlets. Additional air distribution is needed in areas of the building that are not in the ventilation paths shown. This should be accomplished with Kearny pumps. It may be necessary to modify this ventilation plan if the illustrated inlets must be closed to provide adequate fallout protection.

The fans should be firmly mounted in the doorways used as exhaust openings and the generators utilized to power the fans and lighting system should be located in the proximity of the exhaust doorways so that exhaust fumes will be drawn outside.

D. Water Supply

Water is presently supplied to the S-Mart Department Store from a municipal reservoir. However, this source of water should not be counted on in a crisis situation. Water for the shelter population should be stored on site.

The 8,605 shelter occupants of the S-Mart Store should have 45,607 gallons (8,605 shelter occupants x 5.3 gallons per occupant) of water available for a 2-week shelter stay. The automatic sprinkler system stores 650 gallons in a standpipe which leaves almost 40,000 gallons of storage capacity that still is needed. A survey should be conducted to locate sources of containers (steel drums, garbage cans, milk trucks, etc.) in which the water can be stored, and it should be determined whether or not the municipal water supply is of sufficient quantity to meet the requirements of the entire area it serves in the days immediately preceding a nuclear attack. If the supply of water is inadequate, alternative sources of water must be located, or the amount of water made available should be lowered to something less than the ideal level.

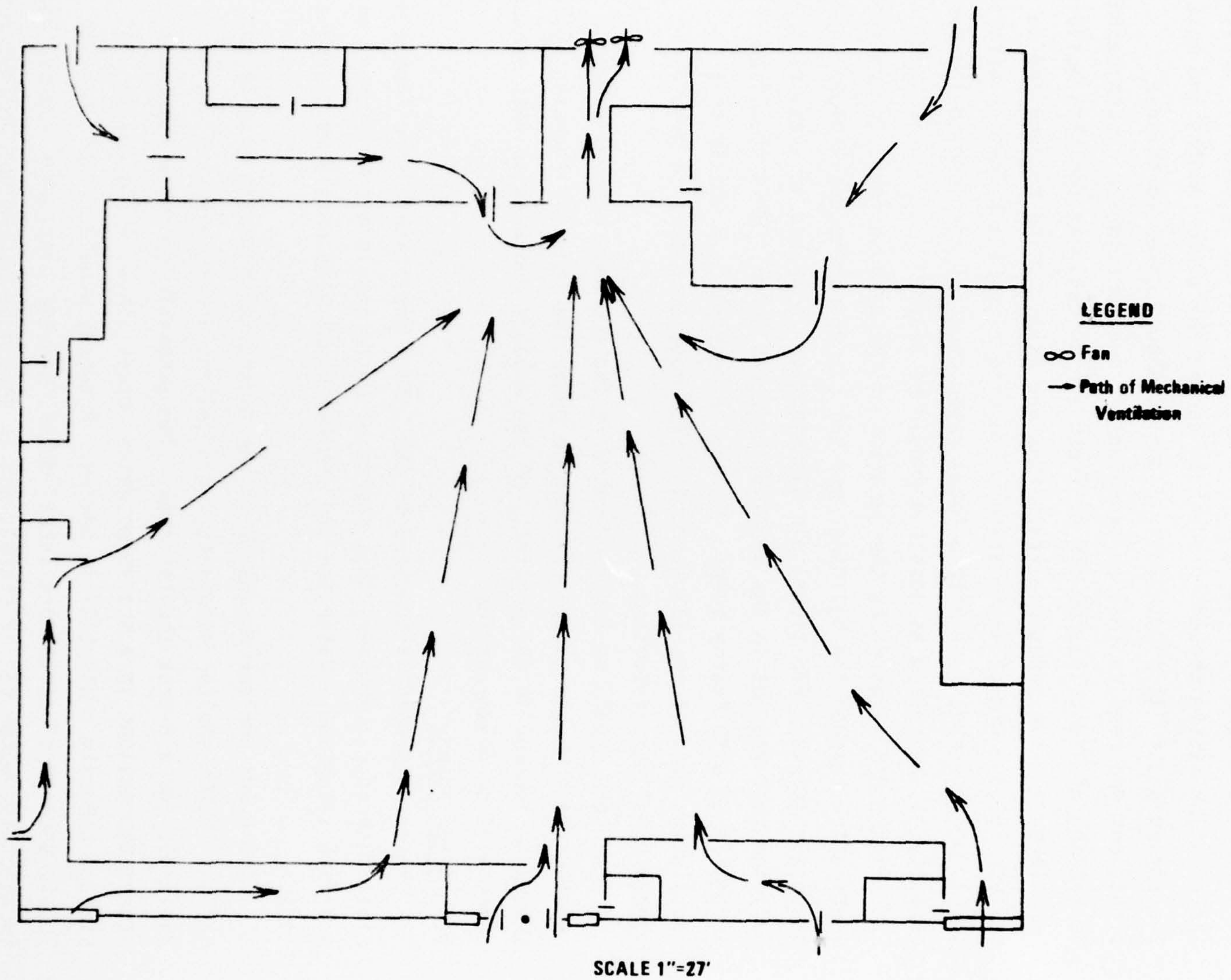


FIGURE D-4. FLOW OF VENTILATION THROUGH S-MART DEPARTMENT STORE

Eighty-six watering points (8,605 shelterees x .01 water point per shelter occupant) should be provided in the S-Mart Department Store. These should be located at points throughout the facility, so that none of the shelter occupants will be required to walk an inordinate distance to a source of water.

E. Excreta Disposal

During a 2-week shelter stay, the 8,605 shelter occupants of the S-Mart Department Store will produce 5,421,150 ounces (8,605 occupants x 45 ounces/occupant day x 14 days) of human excreta, which must be disposed of or stored. At least 172 toilets (8,605 shelter occupants x .02 toilets per occupant) should be made available in this facility. The three existing toilets in the building may not be usable in a crisis situation due either to a lack of flushing water or to an overloaded treatment system; therefore, plans should be made to install 172 temporary toilets.

The most desirable type of temorary toilet is the chemical toilet and these should be used to the extent that they are available. If an insufficient number of chemical toilets is available, removable pail privies should be employed. To the extent possible, the toilets should be located in such a manner that odors will be exhausted from the building. Sources of pumps which could be used to pump sewage from the chemical toilets or from collection containers (such as empty water storage containers) for the removable pail privies to earth pits outside the facility should be identified.

F. Solid Waste Disposal

Over a 14-day shelter stay, from 180,705 pounds to 301,175 pounds (8,605 shelter occupants x 14 days x 1.5 to 2.5 pounds per occupant day) of solid waste is estimated to be produced by the shelter occupants in the S-Mart Department Store. It is further estimated that from 258 to 344 containers of 26-gallon (or less) capacity will be needed to collect the solid waste. These containers should be distributed throughout the facility for the convenience of all of the people sheltered there. The collection containers will need to be emptied into central storage containers once or twice daily. Sources of both collection containers and storage containers should be identified in the planning period. If all of the water storage containers are not needed for human excreta storage as they are emptied, they can be used for solid waste collection. Otherwise, more containers must be supplied. When radiation drops to permissible levels, the storage containers can be emptied in trenches outside the building.

III. EXAMPLE NUMBER 3

BASSETT BUILDING

A. General

The Bassett Building is a rural county office building located in the Southwest. It contains 38 offices and a conference room as shown in the floor plan in Figure D-5, and it has 11,502 square feet of usable floor area (or 1,150 shelter spaces). The building has an artificial lighting system and a mechanical ventilation system. The lighting is more than adequate for a fallout shelter and an emergency generator is available for power. The ventilation system is capable of delivering 20,000 cfm of outside air. There are two restrooms with six toilets, two urinals and four faucets located in the facility. There are also two water fountains in the building. Garbage is collected twice weekly by a private service.

B. Lighting

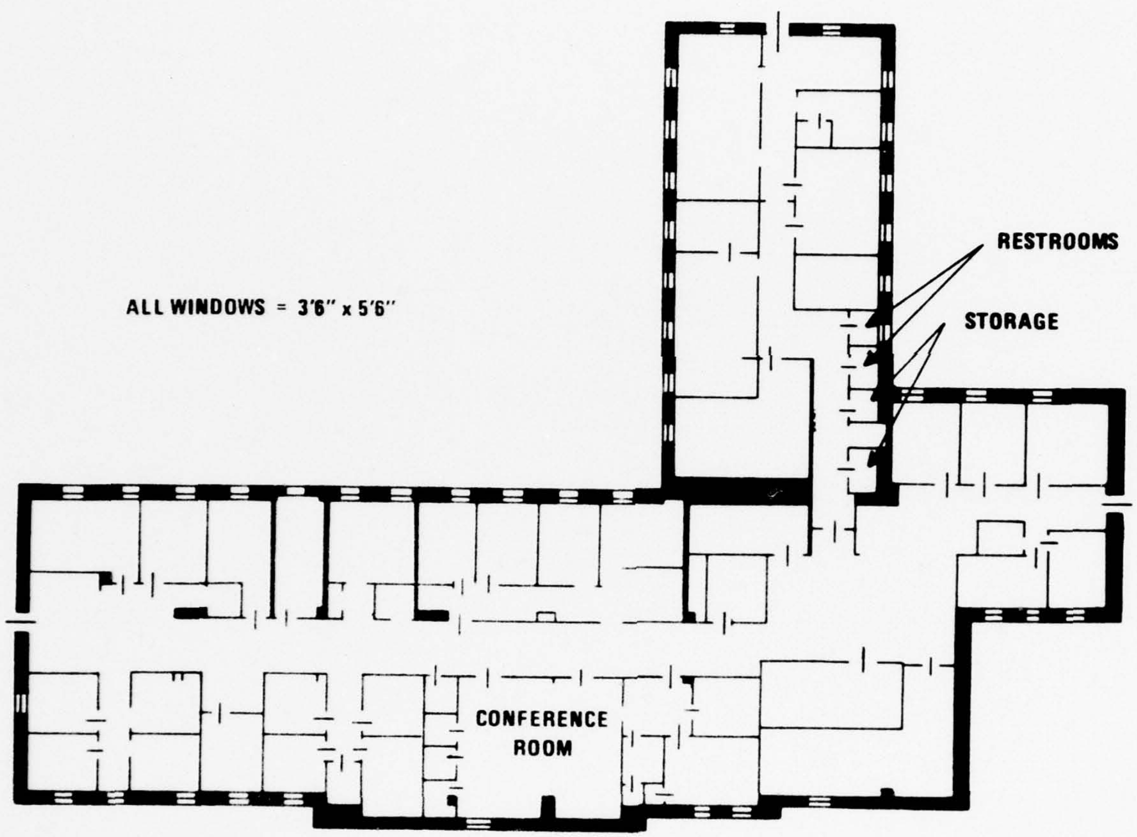
The existing emergency lighting system is adequate for the use of the Bassett Building as a fallout shelter. The engine-generator is connected to the electrical distribution system by a manual transfer switch; therefore, the lighting system is ready for use, should it be needed.

C. Ventilation

The county in which the Bassett Building is located has a zonal ventilation requirement of 15 cfm per shelter occupant. This means that for the 1,150 shelter occupants, 17,250 cfm (15 cfm per occupant x 1,150 occupants) of ventilation is needed. The existing ventilation system delivers 20,000 cfm of fresh air if the damper is opened to admit 100 percent outside air. In this case, it is therefore not necessary to plan for a ventilation system, if an appropriate engine-generator to power the existing mechanical ventilation system can be identified and if the engine-generator can be transported to the Bassett Building and connected to the ventilation system.

D. Water Supply, Excreta Disposal and Solid Waste Disposal

Water is supplied to the Bassett Building from a municipal reservoir, just as in the case of the S-Mart Department Store (Example 2). Therefore, the guidelines given in that example also apply to the Bassett Building. Simliarly, the excreta disposal and solid waste disposal guidelines are also directly applicable in this case.



UNMARKED ROOMS ARE OFFICES

SCALE 1" = 30'

FIGURE D-5. FLOOR PLAN OF BASSETT BUILDING

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RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report 44U-1340 - DCPA Work Unit 1217E
DCPA Contract No. DCPA 01-76-C-0318
Study of Crisis Utilization of Large Shelter Space
Wright, M.D., S.B. York, III, R.H. Hill, and J.S. McKnight
August 1977 (UNCLASSIFIED)

This study consisted of an investigation into the options available for utilizing large special facilities such as tunnels, government installations, and large industrial buildings for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary systems for large groups of people. This was accomplished by first establishing the existing availability of these services and then identifying ways of augmenting the existing services.

An investigation was also made of the possibilities of suitable close-in shelter for key workers.

All of the analyses were made using existing data already collected.

Example problems are included as an appendix.

RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report 44U-1340 - DCPA Work Unit 1217E
DCPA Contract No. DCPA 01-76-C-0318
Study of Crisis Utilization of Large Shelter Space
Wright, M.D., S.B. York, III, R.H. Hill, and J.S. McKnight
August 1977 (UNCLASSIFIED)

This study consisted of an investigation into the options available for utilizing large special facilities such as tunnels, government installations, and large industrial buildings for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary systems for large groups of people. This was accomplished by first establishing the existing availability of these services and then identifying ways of augmenting the existing services.

An investigation was also made of the possibilities of suitable close-in shelter for key workers.

All of the analyses were made using existing data already collected.

Example problems are included as an appendix.

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